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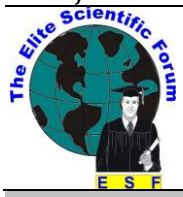

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REVIEW ARTICLE

Freshwater Fish Diversity and Their Conservation Status in Southern Punjab, Pakistan: A Review

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ABSTRACT

Understanding fish diversity and its distribution patterns are principal issues for scientists and managers concerned with the extinction processes of fresh water fish species. The aim of current review is to assess the relevant literature describing the diversity, ecology and current population conservation status of freshwater fish of the Southern Punjab, Pakistan. Peer reviewed papers, published during 1976 to 2017, describing freshwater fish diversity at the study site, were selected. Out of four (04) set criteria, two criteria were regarding diversity and distribution of freshwater fish, whereas the other two were related to conservation status and their ecological importance. In total, 82 freshwater fish species belonging to 17 families have been reported at the study site. It was observed that, out of these reported families, most dominant families were *Cyprinidae* (53.7%), *Sisiridae* (7.3%), and *Bagridae* and *Channidae* 4.9% each. Conservation status of the studied freshwater fish fauna of the Southern Punjab indicated 73% of the total species as least concern, 16% species were not evaluated, 6% were near threatened, 4% were found vulnerable, whereas 1% of the total observed species as data deficient. Published record showed that fresh water fish population is continuously decreasing due to overexploitation, illegal fishing activities and alteration in water flow through diversion and damming. The freshwater fish population has also been reduced intensely due to many factors including pollution, habitat degradation, and overexploitation. In conclusion, certain measures including establishment of nature reserve, simulated proliferation and releasing are needed to conserve fish diversity in the area. Habitat restoration should be given consideration for the restoration of diversity of fish in their natural environment. A complete survey to evaluate the current diversity and conservation status of different freshwater fish species is, furthermore, highly recommended at the study site.

INTRODUCTION

Fish are limbless cold-blooded vertebrate animals with gills and fins that are completely adapted to aquatic mode of life. It is believed that commencement with the primary Chinese, Egyptians, and Greeks eras, fish have been reared and studied for centuries (Betancur et al., 2013). The farming of fish and other aquatic species is termed as aquaculture. The living fish have been classified into three major categories, including jawless fish (aganatha), jawed fish (chondrichthyes) and bony fish (osteichthyes), by ichthyologists. The first two groups are primitive, whereas 95% of the world modern fish are bony fish. Freshwater fish fauna is assumed as the most varied and represents all the warm water fish fauna. Freshwater fish are found in various places including reservoirs, streams, canals, lakes, rivers, and various land-locked waters. Fish resides in aquatic habitat and shows much variation in morphological attributes and biological adaptations (Walsh et al., 2009). About 32,500 fish species have been reported so far globally (Nelson, 2006) that constitute approximately 58% marine, 41% freshwater and 1% diadromous species (Helfrich et al., 2005). Freshwater is the naturally occurring water in canals, rivers, reservoirs lakes, streams, and other land-locked waters (FAO, 2014a) that comprised of about 0.01% of the total volume of earth water (Stiassny, 1996). Freshwater fish reside in these waters that cover 41% of fishes and 20% vertebrate (Helfman et al., 2009). The

freshwater comprise about less than 0.3% of available global water and constitute remarkably more than 15,000 freshwater fish species (IUCN, 2015). Globally, 11,952 fish species are strictly reported as freshwater species (Nelson, 2006), whereas 12,457 fish species have used freshwater habitats at sometimes during their life cycle. Levêque et al. (2008) reported 12,740 freshwater species, whereas Vega and Wiens (2012) cited 15,150 species of the class Actinopterygii as inhabiting habitats including freshwaters (Pelayo-Villamil et al., 2015) found 14,782 species of inland fish.

The term freshwater fisheries include both captured fish and aquaculture of inland fish species for food, income, and recreation. Fish populations of freshwater habitat is continuously decreasing globally due to many factors including, loss of habitat, agricultural and industrial development, overexploitation, pollution, alteration in water flow through diversion and damming. Diversity is the deviation in the genetics and life forms of populations, species, communities and ecosystems that affect the capability of living systems to react the environmental changes. Biodiversity is very important for giving goods and services from ecosystems such as clean water, nutrient cycling, livelihood and food source (Costanza, 1997), which has aesthetic as well as intrinsic value (Hiddink, 2008). For a healthy environment and a quality life, sustaining diversity is, however, very important (Helfrich et al., 2009).

The developing countries that are low-income and deficient in food comprise about 80% of the total reported capture from freshwater (Kapetsky, 2003). Globally, 90% of the captured fish products are consumed by humans (Welcomme et al., 2010). Freshwater fish are mainly essential in addressing "hidden hunger" (Kennedy et al., 2003). These fresh water fish provides significant benefits to human health and well-being including biomedical research, pest control and a connection with the outdoors (Lynch et al., 2016). The fish primarily produced from the wild and farmed is an important source of food. It offers nutritional sources like protein, omega-3 fatty acids, vitamin D, calcium, vitamins B, vitamin A, iron, zinc, and lysine in case of unavailability of other nutritional sources are not available or are very costly (Youn et al., 2014). Fish are essential for brain development and cognition in the first 1000 days of life (Cunha et al., 2015). Freshwater fisheries resources can empower individuals to meet their own physical and psychological needs and provides for their dependents. This may play an important role in poverty alleviation for marginalized populations including ethnic minorities, the rural poor, and women (Weeratunge et al., 2014). Freshwater resources are very imperative for food and nutrition, particularly for rural economies in developing countries (Welcomme et al., 2010). It has been reported that about 60 million people in developing countries depend upon inland fisheries as a livelihood source and women are more than half of the individuals in inland fisheries supply chains (FAO, 2014b). Pakistan has been granted with enormous aquatic resources including marine and freshwater. In total, 193 freshwater fish species has been reported so far in Pakistan (Rafique and Khan, 2012). The recorded fish and fish products consumption is 9.1% as a share of total animal meat. The documented edible fish consumption in Pakistan is the lowest as 0.6 kg per capita per year, whereas in Punjab, Pakistan is 0.2 kg per capita per year (FAO, 2015).

There is distinctive freshwater fish fauna and fish distribution pattern in each continent (Berra, 2001). The physical obstacles disturbing fish dispersal and variations in temperature adaptations amongst the various groups' leads to different distribution pattern. Maximum fish species are found in the tropical and subtropical areas with an overall decrease in diversity towards temperate and polar regions. There is decline in fish species in glaciations experienced continental areas including northern North America, Asia and Europe, whereas some temperate regions, mainly those that were never glaciated are relatively rich in fish species. There is much diversity in freshwater fishes of the equatorial zone and it is difficult to readily characterize them by any particular clades (Levêque et al., 2008).

The rivers, canals, streams, lakes, huge reservoirs, evolved by building dams and barrages, are the main freshwater fisheries resources. Since freshwater fishes resides in various habitats including rivers, streams, natural lakes, wetlands, and springs, demonstrating different taxonomic groups having unique ecological necessities. Freshwater fish are facing a high conservation tragedy (Page and Burr, 1991). Different threats, including environmental stressors (e.g. climate change, pollutants) and the diseases spread, to fish population can be reduced by a greater genetic variation within a fish population (Hilborn et al., 2003). For managers, scientist and other stakeholders working to reduce the current extinction process, understanding biodiversity distribution outlines is the main issue. Freshwater fishes are one of the threatened species and represent the most diverse group of vertebrates (Bruton, 1995). The decline of freshwater fish is a comprehensive phenomenon noticeable on global, regional and local scales (Moyle and Randall, 1998; Duncan and Lockwood, 2001). The deterioration or demolition of habitats due to both pollution and extreme modification (i.e. inhibiting, channelization) and the introduction of exotic species are major threats to freshwater fishes (Allan and Flecker, 1993). The lack of extensive indigenous animal natural diversity has led to limited supply of medicine, less carrier opportunities and unhealthy economy leading to poorer human lives.

Biodiversity for humans is, therefore, as much as important as the clean water and air. It is the need of hour, consequently, to make an extraordinary effort to safeguard wild species for future.

The freshwater fish are the most diverse group of vertebrates and their fauna is believed as highly diverse and represents the warm water fish fauna of Pakistan. In total, 186 freshwater fish species has been reported so far in Pakistan (Department of Fisheries Punjab). Out of all vertebrates naturally found in water, Fish is the most abundant one. The long-term sustainability of many targeted and non-targeted species in an aquatic habitat of Southern Punjab Pakistan is unknown due to improper execution of surveys and lack of population assessments record. Biodiversity comprises various measures of biological organization from the genetic variation within species to the deviation in species richness within entire ecosystems. Conventionally, species level diversity in fishery surveys is the main focus of fish biologists. Different genetically distinct populations can be adjusted to indigenous environments with specific behaviors and life histories. The identification of these changes needs constant backing for consistent and long-term research surveys of fish populations as well as taxonomic and genetic base for precise species identifications. Uniform research surveys, when combined with historical fisheries information (e. g., from written archives or archaeological studies), provide baselines against the future changes in species abundance and magnitude configuration can be identified, and relevant aspects recognized (Jackson et al., 2001; MacKenzie et al., 2002). The influences of variation in biodiversity on functioning of ecosystem are becoming apparent. There are numerous fishery related variations in species and size composition of fish communities are also well established (Garcia, 2006). Fish diversity management requires a precautionary approach by fisheries managers and policy makers.

Diversity and distribution of fish of a habitat is closely associated with different factors including water currents, depth, food availability, breeding sites, and water physicochemical properties. The population of various species is decreasing in range size and abundance inspite of the fact that extinctions have occurred. Although, fish biota of the region as a whole is assorted; however, we need to take action to stop further decrease in fish population (Walsh et al., 2009). The aim of the study was to review the relevant literature to discuss the diversity, ecology and current population conservation status of freshwater fish of Southern Punjab, Pakistan.

Overview of Southern Punjab, Pakistan

Southern Punjab, Pakistan is the land of geological and geographic diversity. Multan, the city of Saint is the center of Southern Punjab (Rafique and Khan, 2012). The southern Punjab that may include districts of Rahim Yar Khan, Bhawalpur, Bhawalnagr, Lodhran, Vehari, Multan, Khanewal, Muzaffar Garh, Dera Ghazi Khan, Rajanpur, Layyah, some parts of Bhakar, Jhang, Tobatek Singh, Sahiwal and Pakpattan as shown in (Fig. 1). The Southern Punjab, Pakistan occupies five rivers including Indus River, Chenab River, Sutlej, Jehlum, and Beas. There are five barrages/ headwork's in Southern Punjab included Islam Barrage on the river Sutlej, Head-Punjnad formed by successive convergence of the five rivers of Punjab, Sidhnai Headworks over Ravi River, Trimmu Barrage and Muhammadwala headworks over Chenab River. The freshwater fish fauna of Southern Punjab is known through a number of comparatively recent studies conducted at different places and times (Mirza and Mirza 2014; Rafique and Khan, 2012). These studies are useful in providing information on species diversity and distribution.

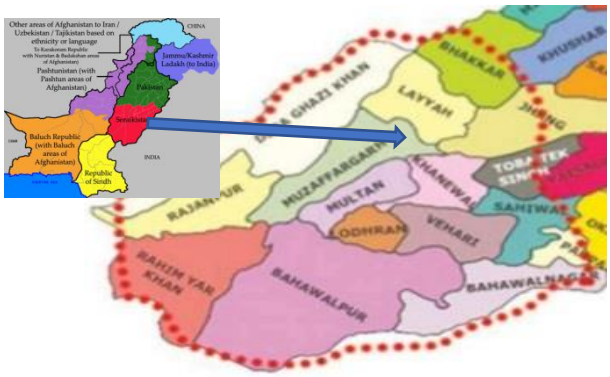

Fig. 1: Map of Southern Punjab Pakistan.

Databases searched out

Peer reviewed papers, published during 1976 to 2017, describing freshwater fish diversity, distribution and conservation status in Southern Punjab, Pakistan, were selected. The selected papers were searched by using the key words 'freshwater fish', 'diversity', distribution' and 'conservation status' in different electronic databases including Google scholar, Web of science, Scopus, Pubmed, Science direct, Springer link, Elsevier and HEC Digital Library. Searched results in which the diversity of freshwater fish in natural reservoirs as well as in aqua-farming was studied that, found in Archives of different national and international journals.

Criteria for the inclusion of papers from the databases

The studies were reviewed to meet the following inclusion criteria;

1. Describing the freshwater fish diversity of Southern Punjab

2. Containing the information regarding the distribution of freshwater in Southern Punjab
3. Presenting the conservation status of freshwater fish of Southern Punjab
4. Provision of data regarding the ecological importance of freshwater fish

Rate of Freshwater fish diversity and its description in Southern Punjab

Freshwater fishes that are inclined to be limited to drainage systems, offer a comparatively conventional system for investigating circulation patterns that may indicate the imprint of past continental and climate changes (Levêque et al., 2008). Freshwater fish fauna of the Indus plain is assumed as highly diverse and represents all the warm water fish fauna of Pakistan. There are some extensive studies regarding fish fauna of the Chashma and Taunsa reservoirs and adjoining areas that have been reported by various scientists (Mirza and Awan, 1976; Mirza, 2006). An aquatic habitat is populated by various forms of aquatic life when fish occupies a prominent place (Mirza and Bhatti, 1999). There are about 180 fish species that have been reported in Indus River (Rafique and Khan, 2012; Mirza and Mirza, 2014). The river Chenab is another most important wetland of Southern Punjab, Pakistan with wide diversity of the flora and fauna. From the river Chenab, 34 species and 1766 number of the fishes were recorded (Altaf et al., 2015). Khan et al. (2008) observed 20 and 22 species from the Chashma and Taunsa barrage, respectively, whereas Muhammad et al. (2016) reported 20 species of freshwater fish at Taunsa Barrage from the Indus River. Hussain et al. (2016) recorded 22 fish species belonging to 10 families from Dera Ghazi Khan, Southern Punjab, Pakistan. In total, 20 fish species belonging to 16 genera were documented from Suleman Mountain Range, Dera Ghazi Khan Region by Hussain et al. (2016), whereas Muhammad et al. (2017) collected 70 species of the freshwater fishes from Taunsa Barrage. Freshwater fish diversity of Southern Punjab, Pakistan described in various published literature is shown in Table 1. In total, 82 freshwater fish species belonging to 17 families have been reported so far at the study site. It was observed that, out of the reported families, most dominant families were Cyprinidae (53.7%), Sisiridae (7.3%), and Bagridae and Channidae 4.9% each (Table 1, Fig. 2). Cyprinidae is the most leading group comprising, in total eight species constituting highest percentage composition with 42% species (Negi and Mamgain, 2013). Similarly, Vijaylaxmi et al. (2010) reported order Cypriniformes as leading one with seven fish species followed by order Siluriformes comprising four species, and the order Channiformes, Mastacembeliformes and Osteoglossiformes each containing one species.

Table 1: Checklist of the freshwater fish diversity of Southern Punjab, Pakistan

Sr. No.	Family	Scientific name	Local name	Conservation status	References
1	*Cyprinidae*	*Labeo rohita*	Rohu	LC	(Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
2	*−do −*	*Labeo calbasu*	Calbans	LC	Altaf et al., 2015; Muhammad et al., 2017)
3	*−do −*	*Labeo bata*	Bata	LC	(Hussain et al., 2016)
4	*−do −*	*Labeo gonius*	Sereha	LC	(Khan et al., 2008; Muhammad et al., 2017)
5	*−do −*	*Labeo boggut*	Bhangana	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
6	*−do −*	*Labeo dyocheilus*	Torki	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
7	*−do −*	*Labeo bogga*		LC	(Muhammad et al., 2017)
8	*−do −*	*Labeo fimbriatus*	Chita rohu	LC	(Hussain et al., 2016)
9	*−do −*	*Labeo diplostomus*	Pahari rahu	LC	(Hussain et al., 2016)
10	*−do −*	*Cirrhinus mrigala*	Mori	LC	(Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
11	*−do −*	*Cirrhinus reba*	Reba	LC	(Altaf et al., 2015; Muhammad et al., 2017)
12	*−do −*	*Catla catla*	Thaila	LC	(Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2016; Muhammad et al., 2017)
13	*−do −*	*Puntius/ Barbodes sarana*	Khurni	LC	(Hussain et al., 2016)
14	*−do −*	*Cyprinus carpio*	Gulfam/ Common Carp	VU	(Khan et al., 2008; Altaf et al., 2015; Hussain et al., 2016; Muhammad et al., 2017)
15	*−do −*	*Ctenopharyngodon idella*	Grass Carp	NE	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
16	*−do −*	*Hypophthalmichthys*	Silver carp	NT	(Khan et al., 2008; Iqbal et al., 2013; Altaf

		molitrix			et al., 2015; Muhammad et al., 2017)
17	*−do −*	*Systomus sarana*	Olive barb	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
18	*Channidae*	*Channa punctata*	Daula	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016; Muhammad et al., 2017)
19	*−do −*	*Channa marulius*	Saul/ Shakir	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
20	*−do −*	*Channa striata*	Sauli	LC	(Muhammad et al., 2017)
21	*−do −*	*Channa gachua*	Dauli	LC	(Iqbal et al., 2013)
22	Bagridae	*Aorichthys aor*	Seenghari	LC	(Hussain et al., 2016)
23	Cichlidae	*Oreochromis aureus*	Blue Tilapia	VU	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
24	*−do −*	*Oreochromis niloticus*	Nile Tilapia	VU	(Muhammad et al., 2017)
25	*−do −*	*Oreochromis mossambicus*	Tilapia	NT	(Iqbal et al., 2013; Hussain et al., 2016; Muhammad et al., 2017)
26	Osphronemidae	*Colisa fasciata*	Bari Khangi	LC	(Iqbal et al., 2013; Hussain et al., 2016)
27	Bagridae	*Rita rita*	Khaga	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016)
28	Sisoridae	*Bagarius bagarius*	Fauji Khaga	NT	(Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2017)
29	Bagridae	*Mystus cavasius*	Tirkanda/Tangaara	LC	(Altaf et al., 2015)
30	*−do −*	*Sperata sarwari*	Sanghari	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015)
31	Schilbeidae	*Eutropiichthys vacha*	Jhali	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016)
32	*−do −*	*Wallago attu*	Malee	NT	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016)
33	Mastacembelidae	*Mastacembelus armatus*	Bam/ Gruj	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016)
34	Notopteridae	*Notopterus notopterus*	Pari	LC	(Khan et al., 2008; Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016; Muhammad et al., 2017)
35	*−do −*	*Notopterus chitala*	Chitali Pari	LC	(Iqbal et al., 2013; Muhammad et al., 2017)
36	Clupeidae	*Gadusia chapra*	Pali	LC	(Iqbal et al., 2013; Muhammad et al., 2017)
37	*−do −*	*Gonialosa manminus*	ND	LC	(Iqbal et al., 2013)
38	*Cyprinidae*	*Puntius sophore*	SophorePopra	LC	(Iqbal et al., 2013; Altaf et al., 2015; Hussain et al., 2016; Muhammad et al., 2017)
39	*−do −*	*Puntius terio*	Terio popra	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
40	*−do −*	*Puntius chola*	Kola popra	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
41	*−do −*	*Puntius punjabensis*	Punjabi popra	NE	(Muhammad et al., 2016; Muhammad et al., 2017)
42	*−do −*	*Puntius ticto*	Ticto/ Ticto popra	LC	(; Iqbal et al., 2013; Altaf et al., 2015; Muhammad et al., 2016; Muhammad et al., 2017)
43	*−do −*	*Puntius conchonius*	Gulabi barb	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
44	Mastacembelidae	*Macrognathus pancalus*	Garoj	LC	(Altaf et al., 2015)
45	Schilbeidae	*Clupisoma garua*	Bachwa	LC	(Khan et al., 2008; Iqbal et al., 2013; Hussain et al., 2016)
46	Cyprinidae	*Aspidoparia morar*	Aam Chilwa	LC	(Iqbal et al., 2013; Muhammad et al., 2016; Muhammad et al., 2017)
47	*−do −*	*Securicula gora*	Bari Chal	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
48	*−do −*	*Salmophasia bacaila*	Choti Chal	LC	(Iqbal et al., 2013; Muhammad et al., 2016; Muhammad et al., 2017)
49	*−do −*	*Salmophasia punjabensis*	Punjabi Chal	LC	(Muhammad et al., 2016; Muhammad et al., 2017)

50	−*do* −	*Osteobrama cotio*	Paliro	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
51	−*do* −	*Crossocheilus diplochilus*	Dogra Machhli	NE	(Muhammad et al., 2017)
52	−*do* −	*Chela cachius*	Cachius Biddah Morriah	LC	(Muhammad et al., 2016; Muhammad et al., 2017)
53	−*do* −	*Ambylpharyngodon mola*	Mola	LC	(Muhammad et al., 2017)
54	−*do* −	*Botia lohachata*	Botia	NE	(Muhammad et al., 2017)
55	−*do* −	*Botia birdi*	Botia	NE	(Hussain et al., 2016; Muhammad et al., 2017)
56	Gobiidae	*Glossogobius giuris*	Tank Goby	LC	(Muhammad et al., 2017)
57	Osphronemidae	*Colisa fasciata*	Bari kanghi	LC	(Muhammad et al., 2017)
58	−*do* −	*Colisa lalia*	Choti kanghi	LC	(Muhammad et al., 2017)
59	Heteropneustidae	*Heteropneustes fossilis*	Singhi	LC	(Iqbal et al., 2013; Muhammad et al., 2017)
60	Sisoridae	*Glyptothorax cavia*	Kani tingara	LC	(Muhammad et al., 2017)
61	−*do* −	*Glyptothorax punjabensis*	Pahari khaga	NE	(Muhammad et al., 2017)
62	−*do* −	*Sisor rabdophorus*		LC	(Muhammad et al., 2017)
63	−*do* −	*Nangra nangra*	Nangra	LC	(Muhammad et al., 2017)
64	Belonidae	*Xenentodon cancila*	Kaan	LC	(Iqbal et al., 2013; Muhammad et al., 2017)
65	Mugilidae	*Sicamugil cascasia*		LC	(Muhammad et al., 2017)
66	Siluridae	*Ompok pabda*	Paharipafta	NT	(Iqbal et al., 2013; Hussain et al., 2016)
67	Cyprinidae	*Tor macrolepis*	Sindh Mahsheer	NE	(Hussain et al., 2016)
68	−*do* −	*Barilius vagra*	Chalwa	LC	(Hussain et al., 2016)
69	−*do* −	*Barilius modustus*	Chalwa	NE	(Iqbal et al., 2013; Hussain et al., 2016)
70	−*do* −	*Salmophasia bacaila*	Choti Chal	LC	(Hussain et al., 2016)
71	−*do* −	*Garra gotyla*	Pathar Chat	LC	(Hussain et al., 2016)
72	−*do* −	*Securicula gora*	Bari Chal	LC	(Hussain et al., 2016)
73	−*do* −	*Crossochelus diplocheilus*	Dogra Pathar Chat	LC	(Hussain et al., 2016)
74	−*do* −	*Schizothorax plagiostomus*	Sawati	DD	(Hussain et al., 2016)
75	−*do* −	*Cyprinion watsoni*	Sabzak	LC	(Hussain et al., 2016)
76	−*do* −	*Barilius pakistanicus*	Pakistani Chalwa	NE	(Hussain et al., 2016)
77	−*do* −	*Salmophasia punjabensis*	Punjabi Chal	NE	(Hussain et al., 2016)
78	Sisoridae	*Gagata cenia*	Gageeta	LC	(Iqbal et al., 2013)
79	Balitoridae	*Schistura macrolepis*	ND	NE	(Iqbal et al., 2013)
80	Balitoridae	*Schistura shadiwaensis*	ND	NE	(Iqbal et al., 2013)
81	Clupeidae	*Gudusia chopra*	Shad	LC	(Iqbal et al., 2013)
82	Cobitidae	*Botia lohachata*	ND	NE	(Iqbal et al., 2013)

Note: ND - Not determined; LC - Least concern; VU - Vulnerable, NT - Near threatened; NE - Not evaluated; DD - Data deficient.

Conservation status of the studied freshwater fish fauna of Southern Punjab with reference to IUCN red list (IUCN, 2015) was found as least concern 73%, not evaluated 16%, near threatened 6%, vulnerable 4% and data deficient 01% (Table 1, Fig. 3). Species diversity showed that changed habitat and high altitude support less fish species, whereas variety habitat like shallow pool and deep pools are the major habitats contributing to the maximum diversity. Cyprinidae appeared as the main leading group and, therefore, safeguarding of these specific habitats is endorsed for conservation and management of the fish biodiversity of Southern Punjab, Pakistan.

Fishes are found around or near the top of the food chain and are indicator of a stable aquatic ecosystem (Gorman and Karr, 1978). Fish diversity comprised of species richness (quantity of species in a definite area), species abundance (relative amount of species) and phylogenetic diversity **(**relation between various fish species groups) (Gorman and Karr, 1978). For description and assessment of fish community diversity, different parameters including species composition and species richness are used in various studies (Friedlander and Parrish 1998; Hewitt et al., 2008). The species diversity and distribution in aquatic resources of Southern Punjab, Pakistan is presented in Table 2.

Structure and appearance

All the species have different characteristic with various shape, size, pigmentation pattern, fins disposition and additional external features that help in

recognition and identification. Douglas and Matthews (1992), and Moyle and Randall (1998), provided the information regarding external morphology of fish. A usual fish is a compact unit containing head, trunk and tail grade smoothly into one another. The anatomical divisions, however, can be differentiated by location to a mixture of internal and external borders. Body shape and fin size influence the static position and moving operation in stream fish (Douglas and Matthews, 1992). A cylindrical body with a lower surface area to body volume with stiff ratio, small fins helps in their existence in swiftly flowing riffles, whereas fishes residing in slowly flowing pools are anticipated to have a deep, laterally compressed body with big fins that helps in their turning ability and quick angular acceleration (Bisson et al., 1988). Most fish in minor, steady streams are superficially habitat experts with established various morphological and behavioral variations to show specific habitat types (Wood and Bain, 1995). The morphological measurements, therefore, can be a valuable tool for forecasting the habitat preferences of stream fish (Chan, 2001).

Body shape: There is a great diversity in fish body shape. The "typical" fish body shape is almost cylindrical and conical at both ends **(**Fig. 4), which is quite energy efficient for swimming. In comparison with other body shapes, this shape produces less drag (the opposing force an object generates as it travels through water). There are three different ways including compression, depression and elongation by which different species of fish deviate from the fusiform body shape (Strauss and Bond, 1990).

Coloration: Most fish species have pigmentation with darker dorsal surface compared with the ventral one. When viewed from above, the dorsal side of a counter shaded fish mergers with the black depths or bottom of the habitat. When viewed from below, the ventral side blends in with the lighter surface of the habitat. A counter-shaded fish is safer for predators and prey to spot. To blend in with in the environment, some fish are colored. Numerous bottommost dwelling fishes contest the substrate and even change color when they move towards a new site. Greatly distinct features may puzzle predators. Various fish, for instance, have a fabricated eyespot that can fool a predator into striking in the incorrect way, letting the fish to escape. In some fish species, coloring may also act as an advertisement to other animals.

Head structures: Almost all fish species contain a pair of eyes, a pair of nostrils, a mouth, cephalic (head) lateral line canals and some sort of gill opening in the external structure in the head region (Fig. 4). There is a variation in placement of eyes that depends upon the fish behavior and its habitat. Fishes having eyes far anterior had generally overlying visual fields providing some degree of binocular vision and, therefore, depth perception. Eyes located more laterally or dorsally, in contrast, provide diverse fields of view (Strauss and Bond, 1990). Seeing under water and the fish habitat diversity has resulted several variations in the anatomy and role of fish eyes. Besides these workable alterations, the fish eye remains growing during life, changes and enhances fresh cells constantly. Regarding three major functions of the eye including light collection, images focusing on retina (accommodation) and images transformation into neural signals. Fish eyes are, however, comparable to all other eyes. Some species have eyes positioned for a field of vision below or above their bodies. Fish can detect color. The eyes are round and focus is achieved by moving the lense in and out, not reshaping the lens as in mammals.

Nostrils: In most bony fishes, there is no connection between nostril**s** and mouth or gills and are positioned in front of each eye. The nostrils may be either single, divided into anterior and posterior portions by a flap, or double, with two apertures very close to each other or divided by up to half the length of the head on each side of the midline (Strauss and Bond, 1990). In contrast to most of the vertebrates, the fishes nares are not interconnect with the mouth cavity and cannot be used for breathing are adapted for olfaction only.

Barbels: Sensory barbels are found on the anterior portion of the head and are generally related with the nares and mouth, particularly the maxilla and mentum. These barbels may be very elongated and protrusive, as are the "whiskers" of many catfishes (Siluriformes) or very small and hidden within the folds of skin between the jaw bones, as in some minnows (Cyprinidae). The size, location and form of branching, and amount of barbels are taxonomically vital (Strauss and Bond, 1990). These barbels are used to identify pray and are profoundly invested with sensory cells.

Table 2: Freshwater fish diversity and its distribution in Southern Punjab, Pakistan.

Sr. No.	Diversity/ Richness	Location	Study period	Reference
1	70	Taunsa Barrage	2013-2014	(Muhammad et al., 2017)
2	20	Taunsa Barrage	2013-2014	(Muhammad et al., 2016)
3	22	Ghazi Ghat	2007-2008	(Hussain et al., 2016)
4	3	Head Trimmu, River Chenab	2015	(Azmat et al., 2016)
5	20	Dera Ghazi Khan Region	ND	(Hussain et al., 2016)
6	34	Chenab River	2006-2007, 2009-2010, 2013-2014	(Altaf et al., 2015)
7	20	Chashma (River Jhelum)	2005-2006	(Khan et al., 2008)
8	22	Taunsa (River Indus)	2005-2006	(Khan et al., 2008)

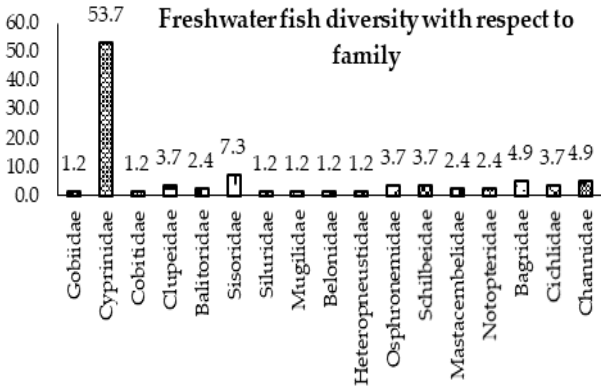

Fig. 2: Families (based on the data presented in Table 1) of the freshwater fish species found in Southern Punjab.

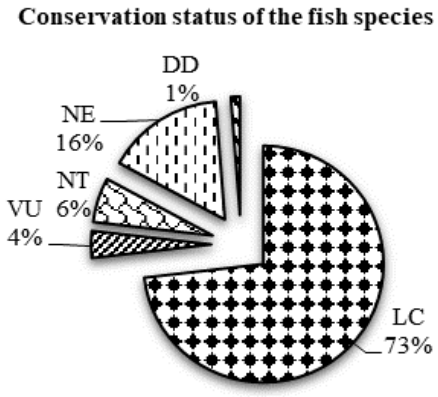

Fig. 3: Conservation status (based on the data presented in Table 1) of the freshwater fish species of Southern Punjab, Pakistan

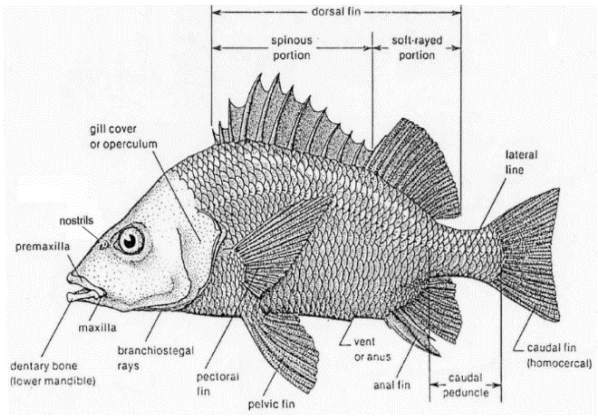

Fig. 4: External morphology of fish (Strauss and Bond, 1990)

Scales: Scales can be defined as a layer of plates that cover and protect most bony fishes species. Hard plates covering fish body or scales, do not only serve as external protection but are also important as one of the tools for species identification (Farah-Ayuni et al., 2016). Some bony fishes may have scales only on portions of their body, whereas some species have no scales. There are three different kinds of scales including ctenoid, cycloid and ganoid (Fig. 5). The spiny-rayed fish contains ctenoid scales with various rows of spinules or ctenii on the posterior border, whereas naturally, soft-rayed fishes contain *cycloid* scales having flat posterior borders. Specific spiny-rayed fishes although hold simply cycloid scales. Other spiny-rayed species display equally ctenoid and cycloid scales. There are various types of scales with different size on the head or body regions or may be absent from some definite areas. These scales can be used as a useful taxonomic feature, due to the variation, even in closely related species (Hollander, 1986). The whole body of a fish is covered by mucus layer that is secreted by fish itself. Mucus helps protect a fish from infection. Fish scales are easy to distinguish, non-destructive and undigested by mammals' digestive system (Ibanez and O'Higgins, 2011) and because of that, they can be very useful to provide taxonomic information which can be used to distinguish different species (Harabawy et al., 2012). Scale morphologies can also be used to determine the age of the fish (Esmaeili and Ebrahimi, 2006), the sexes of the fish, and the pollution status of the water body based on the size of the scales of the same fish (Johal and Sawhney, 1999).

Lateral line: A noticeable feature of the trunk and tail of most fishes is the *lateral line* sensory system (lateral line), whereas in a few fish groups including herrings lack the system on the body. The sensory pores of the system are generally related with specific scale rows in the presence of scales. The lateral line normally paths from the top of the opercular opening to the caudal fin (Fig. 4), however it can range onto the caudal fin, or even could be incomplete. These incomplete lateral lines are defined by observing the location of the terminal pore with respect to other noticeable body features including fins (Strauss and Bond, 1990). Interruption of the lateral line is encountered in some families, including the *Cichlidae*, where the line continues posteriorly some scale rows under the disruption.

Mouth and operculum: Bony fish feeding habits can be better judged by mouth shape and size. A flat thin cover the operculum protects the four pairs of gills in bony fish. Three bones form the borders of the mouth. The lower jaw is formed by the mandible, whereas the lateral and dorsal portions of the mouth are made by premaxilla and maxilla. The head may also contain various spines (predominantly from the pre-opercular bone) (Strauss and Bond, 1990). An operculum, a flexible plate, protects the gills.

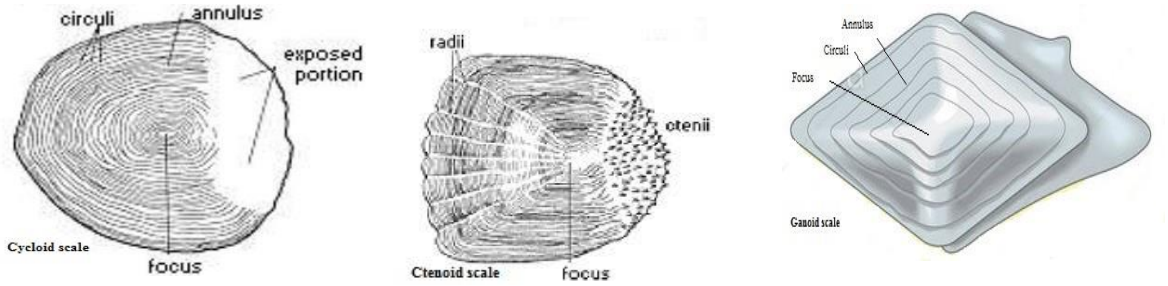

Fig. 5: Types of scales present in modern fish. (Source: Internet)

Fins: Fins are important body part of all fishes that helps in swimming and balancing the fish body. Bony fish families, however, have some fusion and reduction in fins. Paired pectoral and pelvic fins are usually present together with the median dorsal and anal fins in bony fish (Fig. 4) and are supported by horny dermal fin rays in modern fish. The true spines and soft rays are two basic types of fin rays. Spines lack joints and are unbranched with single, median structures and are located generally in the anterior part of a single fin or in the anterior of two separate fins. Species can be distinguished by the shape and size of dorsal fins. The caudal fin is noticeable in most fish and can be condensed or lacking in eel-shaped species. The shape and size of caudal fin mostly the fish family or genera. Common shapes comprise truncate or squared, with a minor depression in the middle, forked, crescent-shaped, rounded, and sharp. Caudal fins can be constant with one or both of the dorsal and anal fins (Strauss and Bond, 1990). Fish are supported by horny dermal fin rays in modern fish. The major functions of fins include;

1. Some fish are stable due to paired pelvic fins, whereas these fins supports in slowing in some other fish species.
2. The dorsal fin helps in keeping fish upright and steady and also used for swift turns.
3. The caudal fin is used to forward and backward movement.
4. The anal fin adds stability.

Ecological and economic importance

During the last 30 years, there is a greater decrease in freshwater biodiversity compared with terrestrial or marine biodiversity possibly mainly due to a decrease in river flow rates (Plafkin et al., 1989). Different factors including ever increasing temperatures, lower precipitation and greater water withdrawal for agriculture and other human consumption may continue this decline in freshwater diversity (Alcamo et al., 2003). This further regression can, therefore, adversely influence the freshwater biodiversity. This freshwater and inland waters biodiversity establish a valued natural resource, in terms of culture, economic, scientific, education and aesthetic. Their preservation and organization are critical for humans because this freshwater biodiversity leads to a valuable natural resource in terms of economics, aesthetic, education and science as well as in culture. There are different environmental problems being faced by rivers and streams mainly related to human activities in the riverside areas (Young et al., 2004). The human activities have adversely effected the degradation of stream and riverine ecosystem (Raghavan et al., 2016) resulting in modifying the function and structure of stream biota (Stoddard et al., 2006).

The continuous overexploitation of global fish resources alarms societies, not only in terms of a reduction in fish populations but is equally essential for eating and entertaining activities. Various ecosystem services caused by fish populations are also at risk, with great concerns regarding biodiversity, functioning of the ecosystem, and eventually human welfare (Holmlund and Hammer, 1999). The nutrient cycling due to its importance regarding ecosystem functioning and resilience are considered as fundamental ecosystem services. These are eventually essential for human presence, regardless of whether humans are aware of it or not. All demand derived ecosystem services eventually rely on natural systems and the fundamental ecosystem services provided by fish, and cannot be replaced by technological improvements (Holmlund and Hammer, 1999). Growing attention in between biodiversity and ecosystem function stems relation, at least partly, from the concern that anthropogenically determined drops and variations in biodiversity will decrease or change the goods and services provided by ecosystems (Millennium Ecosystem Assessment, 2005; McMahon et al., 2012). Fresh water ecosystem, of all the ecosystems on the planet, ensures the highest biodiversity (Dudgeon et al., 2006). These freshwater ecosystem supplies humans with a multitude of goods and services (Baron et al., 2002) and majority of these items are delivered directly or indirectly by the biota (Covich et al., 2004; Loreau, 2010). Due to biodiversity losses that are occurring at a greater rate than marine or terrestrial environment, the freshwater ecosystem is among the top risked ecosystems (Covich et al., 2004; Ricciardi and Rasmussen, 1999). Subsequently, a

reduction in species richness in freshwaters may result in harmful effects on the supply of services (Macadam and Stockan, 2015).

About 94% of freshwater fish are found in developing countries that provide food and a livelihood for them. It also contributes to the general economic wellbeing because of export product trade, tourism and refreshment (Worldfish Center, 2002). Freshwater fishes comprise above 6% of the world's animal protein for humans annually (Ricciardi and Rasmussen, 1999). The global values of freshwater ecosystem including fish as food, freshwater to drink, formation of climate and rain via hydrological cycle, ecosystem sustenance, and recreation that yield a value estimated in trillions of dollars (Reid et al., 2013). Consumption of other aquatic organisms by fish may adjust trophic structure and affect the constancy, elasticity and food web dynamics of aquatic ecosystems by varying because fish pass from one life stage to another. The feeding configuration of fishes may further affect the sequential accessibility of nutrients and the potential for algal buds in highly nutritious lakes, since fish mineralize nitrogen and phosphorus through excretion and defecation resulting in availability of these nutrients for primary production. The managerial control of vector borne diseases including schistosomiasis and malaria can also be done by fish. These types of services usually are not related to any definite economic market value. The 'demand derived ecosystem services', including recreational values, are made by human values and demands, and are not essentially important for the subsistence of human cultures.

Threats

Various factors add to decrease in freshwater fish species and their habitat loss. These may comprise of (i) inadequate knowledge of the ecosystem services provided by river fish; (ii) dams and impoundments; (iii) climate transformation; (iv) partial understanding of the fish and river-flow relation; (v) water pollution, particularly spills of toxic wastes (i.e. oil and petroleum goods, industrial acids, pesticides, and fertilizers); (vi) sedimentation from agriculture, construction, logging and mining; (vii) introduction of exotic species of fish; (viii) overfishing; (xi) exotic stress on native fish.

Conclusions

It is evident from the literature that diversity and distribution of freshwater fish are closely associated with different factors including, water depth, food availability, breeding sites, topography, water current and its physicochemical properties. About 82 freshwater fish species have been reported in nature reserves of Southern Punjab, Pakistan. Species diversity showed that improved habitat and greater altitude maintains less fish species, whereas variety of habitats including shallow and deep pool is the main habitats leading to the supreme diversity. The largest threats to fish diversity in their natural habitat may include loss of habitat, agricultural and industrial development, overexploitation, pollution, hydrological alterations including construction of dams, barrages/ headworks, and interruption between the river and its lakes. In conclusion, definite measures including establishment of nature reserve, simulated propagation and releasing are needed to conserve fish biodiversity in the area. Enhanced simulated releasing and rehabilitation of habitat, additionally, would be considered immediately to preserve the biodiversity of fresh water fish in the area. A complete survey to evaluate the current diversity and conservation status of different freshwater fish species is, furthermore, highly recommended at the study site.

Recommendations

Following steps may be adopted to improve the present biodiversity condition;

1. Generating wakefulness regarding the significance of freshwater biodiversity.
2. Strengthening the base for fisheries management and aquaculture development through improved data collection and scientific assessment.
3. Executing studies to recognize the economic importance of freshwater biodiversity.
4. Preparation of field guides and handbooks and their distribution among the natives of the area.
5. Boosting the broadcasting of relevant literature as part of environmental assessments.
6. Reducing by-catch and discards using more selective gear and fishing operations.
7. More efforts need to be devoted to identifying the problems that may obstruct the ability to conserve and restore the freshwater fish diversity.

Authors' contribution

FB has made significant contribution to conception, literature review, acquisition and interpretation of data. MMN and ANA corrected Tables and designed graphs. FB and MA revised the manuscript very critically and gives final approval of the version to be submitted.

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