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Assessment of diversity and distribution of Bivalves (Mollusca: Bivalvia) in the Indus River District Mianwali, Pakistan

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Abstract

Fresh water mussels have never been the paid attention in freshwater water aquaculture of Punjab with reference to their diversity and distribution. Total number of 300 fresh water bivalves were collected from different selected sites of the River Indus i.e. Chashma Barrage, Jinnah Barrage and Dhair Yaru wala. The specimens were identified on the basis of recent identification keys and diagrammatic description provided in them, to understand the biodiversity of the bivalvia in these localities. It was found that the specimens belonged to ten species, five genera and only to the family Unionidae. The species abundance along with monthly variation of these species at various sites was estimated. The data was subjected to Shannon & Weiner Diversity index showing that all selected sites (Chashma barrage, Jinnah Barrage & Dhair Yaru wala) of river Indus had significant species diversity of the fresh water bivalvia belonging to the family Unionidae.

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Introduction

Bivalves are mollusks with two valves surrounding the body composed of calcium carbonate, either as calcite or aragonitic crystal structure. These molluscs dont have a head. The whole visceral mass is enclosed in a single foot with two pair of gills. The sexes are separate. North America is the most diverse in terms of freshwater bivalve fauna with 300 species with complete description dominated by Unionids (Bogan, 1998). In Europe there are about 48 bivalve species excluding invasive species with 16 species belonging to Family Unionoidae and 32 species belonging to family Veneroidae species (Nagel *et al*., 1998). The mangroves of Southeast Asia inhabits a number of bivalves (Morton, 1976). The total number of freshwater bivalves for Asia is not known although it is expected that in Asia, Sounth Asia and China is highly diverse in species of family Unionoidae following central and east North America (Banarescu, 1990). The Unionidae include 53 species described in India (Subba Rao, 1989) 38 species described in China (Liu, 1979), and 33 species described in Thailand (Brandt, 1974). There are 18 species belonging to Hyriidae, two species belonging to Corbiculidae and 17 species belonging Sphaeriidae out of 37 described bivalve species in Australia (Ponder, 1997). No Comprehensive data has been generated on freshwater bivalve diversity from South America, as the reports at the local and national are fragmentary for the two major families named Hyriidae and Myycetopodidae. The family Mutelidae is restricted only to the African continent and 172 bivalve species belonging to this family have been recorded in Africa (Daget, 1998).

The freshwater bivalves act as natural filtering in lakes and rivers as they consume large quantities of diatoms, blue-green algae, bacteria, organic particles, as well as silt and absorb heavy metals (Morton, 2012). Freshwater mussels are good quality indicators of ecological circumstances as they are long-lasting, they bio-concentrate contaminants, and they are responsive to changes in ecological surroundings (Havlik and Marking 1987; Williams and Neves 2003).

Existing mussels and their exhausted shells helps to progress situations for other organisms by giving bodily structure, stabilizing and bioturbating sediments, and influencing food accessibility straight and ultimately during bio deposition of organic matter and nutrient discharge. Live mussels and relic shells also provide a relatively stable substrate in dynamic riverine environments for a variety of other macro invertebrates (Tucker & Thieling 1998). Mussel plenty effects on nutrient progress and cycling depending on, species composition and environmental situation and also influences multiple trophic levels. They have been exploited worldwide for food, ornamentation and pearls throughout human history (Vaughn, 2008).

The freshwater mussels have attractive and significant natural connections with their environments and to the humans (Graf, 2009). Study on molluscs indicate that in many freshwater systems molluscan populations may be playing a central role in supporting both local and ecosystem level biodiversity (Sharma *et al*., 2009). From an economic perspective, mussels have been valued for their beauty, shell material and natural pearls for centuries. The first large commercial use of mussels began in 1889 when the German button maker pioneered the use of freshwater mussel shells in America (Thiel & Fritz, 1993). They have been used globally for pearls, foodstuff and decoration right through human record. Geologic facts from South Africa indicates that methodical human use of marine capital happening about 60,000 to 70,000 years ago (Volman, 1978).

Though a lot of work has been done on the hydrological and macro benthic faunal aspects on lotic freshwater bodies by earlier workers Dutta *et al*., (2000), but no work has been done on the molluscan diversity Mushtaq (2007) and Sawhney (2008). There is a need for monitoring the status and trends of freshwater biodiversity in order to quantify the impacts of human actions on freshwater systems and to improve freshwater biodiversity conservation.

Current projects carrying assessment of freshwater biodiversity focus mainly on leading-better-known groups such as fish, or identify keystone species and/or endemic freshwater systems for conservation purposes (Lévëque *et al*. 2005).

Recent projects are on the evaluation of freshwater biodiversity for some known group's i.e fish or other groups, mostly related to conservation strategies (Revenga and Kura, 2003; Groom bridge and Jenkins, 1998; Lévëque, 2002). Freshwater molluscs are one of the most diverse and imperiled groups of animals, although not many people other than a few specialists who study the group seem to be aware of their troubles. Malacologists should play active role in conservation, including research, conservation management strategies, and education (Lydread *et al*., 2004). Thirty-five freshwater species have gone extinct as a result of human-caused habitat loss and 64 species are currently listed as endangered (Master and Flack 1997). No previous data regarding the fresh water bivalvia species have been documented in this part of the world. This is the first ever study on the assessment of the diversity and distribution of the bivalves in the Indus River of the Mianwali District, Pakistan showing that there is a great potential in Indus River to harvest this natural resource not only in terms of ecological but also in terms of economic uplift of the country.

Materials and method

Sampling

The molluscs of the littoral zone were collected by hand picking and the small species were separated using a sieve. The frozen samples were brought to the laboratory, washed and then preserved in 70 percent alcohol. Live mussels were stored at a low temperature and were placed in the coldest part of refrigerator.

Identification

All samples were subjected to morphometric measurements including length, width and height of shells in order to identify the collected specimen. Images of all samples were also taken along with. These parameters were then compared with standard parameters of different species according to Damjanov and Liharev, 1975 and the data was subject to statistical calculations.

Species Diversity Index

Species diversity Index is the effective number of different species that are represented in a collection of individuals.

Species diversity consists of two components, species richness and species evenness. Species richness is a simple count of species, whereas species evenness quantifies how equal the abundances of the species are. Species diversity calculated by using formula given by Shannon-Wiener.

The Shannon index, sometimes referred to as the Shannon-Wiener Index or the Shannon-Weaver Index, is one of several diversity indices used to measure diversity in categorical data.

It is simply the Information entropy of the distribution, treating species as symbols and their relative population sizes as the probability using formula.

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Where S is the total number of species and p_i is the frequency of the *i*th species (the probability that any given individual belongs to the species, hence p). It can be shown that for any given number of species, there is a maximum possible H', $H_{max} = \ln S$ which occurs when all species are present in equal numbers.

Results

Site wise analysis of species

Species abundance at Chashma barrage

Anodonta implicata dominated all other species at chashma barrage. Whereas *Strophitus undulatus* was second abundant species and had equally riched with *Anodonta couperiana*. *Anodonta californiensis* and *Anodonta arcaeformis* were found less in number and almost equally riched. The *Unio crassus was* very fewer in number. The species named *Sinanodonta woodiana, Anodonta cygnea, Anodonta anatina* and *Lamellidens marginalis* were found absent at Chashma Barrage (Table 1, Fig. 1).

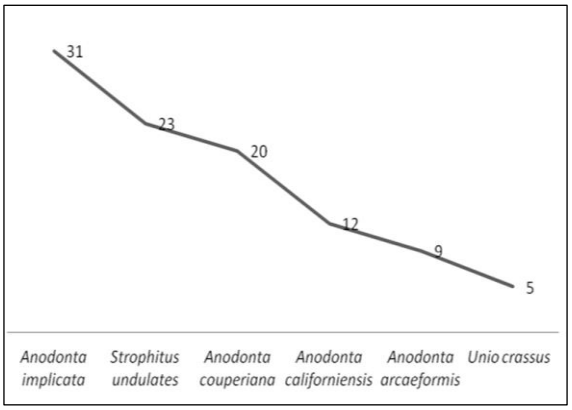

Fig. 1. The Occurrence of Bivalve Species at Chashma Barrage.

Table 1. Species abundance of Bivalvia at Chashma barrage.

Sr. No	Species	Number
1	*Anodonta implicate*	31
2	*Strophitus undulates*	23
3	*Anodonta couperiana*	20
4	*Anodonta californiensis*	12
5	*Anodonta arcaeformis*	09
6	*Unio crassus*	05
	Total	100

Species abundance at Jinnah barrage

Anodonta arcaeformis dominated all other species at Jinnah barrage. Whereas *Unio crassus* was second abundant species and ran side by side with *Anodonta couperiana*. *Sinanodonta woodiana* were found less in number than above three mentioned species. *Anodonta implicata* was also found.

The *Anodonta anatina* was very fewer in number. The species named *Anodonta cygnea, Strophitus undulates, Anodonta californiensis* and *Lamellidens marginalis* were found absent (Table 2, Fig. 2).

Table 2. Species abundance of Bivalvia at Jinnah barrage.

Sr. No	Species	Number
1	*Anodonta arcaeformis*	28
2	*Unio crassus*	24
3	Anodonta couperiana	21
4	*Sinanodonta woodiana*	14
5	*Anodonta implicate*	09
6	*Anodonta anatine*	04
	Total	100

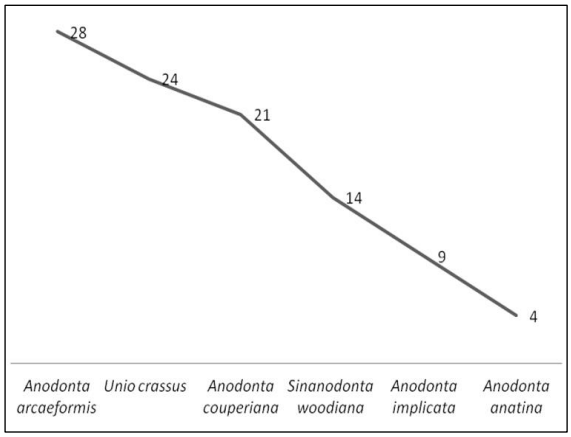

Fig. 2. The Occurrence of Bivalvia Species at Jinnah Barrage.

Species abundance at Dhair yaru wala

Anodonta implicata dominated all other species at Dhair yaru wala. Whereas *Strophitus undulates* was second abundant species followed by *Sinanodonta woodiana* and *Anodonta cygnea* which were almost similar in numbers. *Lamellidens marginalis* was also found. Anodonta couperiana, *Anodonta californiensis Anodonta anatina*, *Anodonta arcaeformis* and *Unio crassus* were not found (Table 3,Fig. 3).

Table 3. Species abundance of Species Bivalvia at Dhair yaru wala.

Sr. No	Species	Number
1	*Anodonta implicata*	33
2	*Strophitus undulates*	23
3	*Sinanodonta woodiana*	18
3	*Anodonta cygnea*	15
4	*Lamellidens marginalis*	11
	Total	100

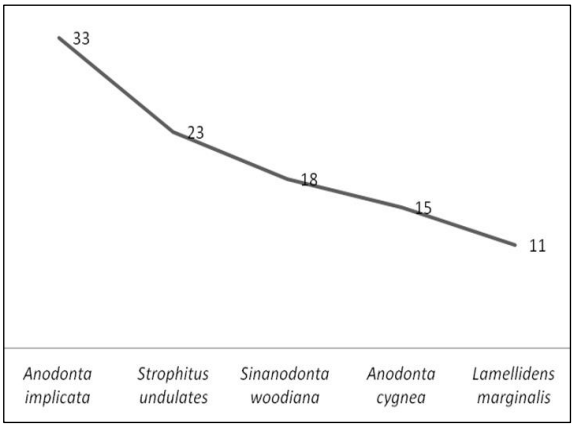

Fig. 3. The Occurrence of Bivalve Species at Dhair Yaru wala.

Species abundance of Bivalvia Species at River Indus

Anodonta implicata dominated all other species followed by *Strophitus undulates* and *Anodonta couperiana* respectively and were almost similar in abundance. *Anodonta arcaeformis, Sinanodonta woodiana* and *Unio crassus* were similar in abundance following *Strophitus undulates* and *Anodonta couperiana*. The *Anodonta anatina* were least in abundance following *Anodonta cygnea, Anodonta californiensis,* and *Lamellidens marginalis* of similar abundance (Table 4-Fig. 4).

Table 4. Bivalvia Species Abundance at River Indus.

Sr. No	Species	Number
1	*Anodonta implicata*	73
2	*Strophitus undulates*	46
3	Anodonta couperiana	41
4	*Anodonta arcaeformis*	37
5	*Sinanodonta woodiana*	32
6	*Unio crassus*	29
7	*Anodonta cygnea*	15
8	*Anodonta californiensis*	12
9	*Lamellidens marginalis*	11
10	*Anodonta anatina*	04
	Total	300

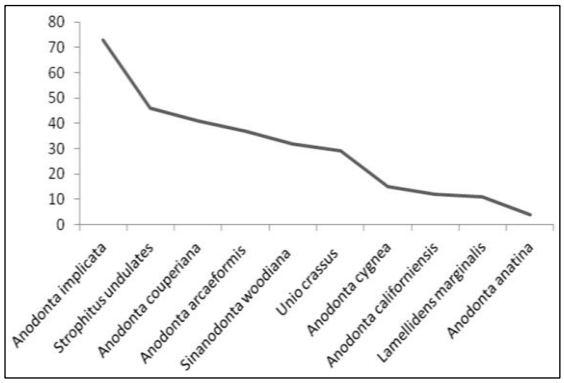

Fig. 4. The Occurrence of bivalvia species at River Indus**.**

Monthly species variation of bivalves

Monthly species variation of bivalves at Chashma barrage

Anodonta implicata was leading species in terms of abundance each month at Chashma barrage however *Unio crassus* was least in number followed by *Anodonta arcaeformis Anodonta californiensis Anodonta couperiana. Strophitus undulates* was found second high in number.The same trend of occurence was found throughout the sampling period (Fig. 5).

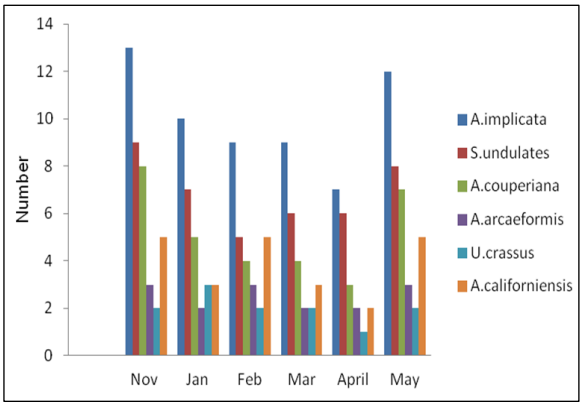

Fig. 5. Monthly species variation of bivalves at Chashma barrage.

Monthly species variation of bivalves at Jinnah Barrage

The *Anodonta couperiana* was leading each month at Jinnah barrage followed by *Sinanodonta woodiana*, *Unio crassus*, *Anodonta arcaeformis*, *Anodonta implicata* respectively ,however, *Anodonta anatine* was found least in number. The similar trend of distribution was found throughout the sampling period (Fig. 6).

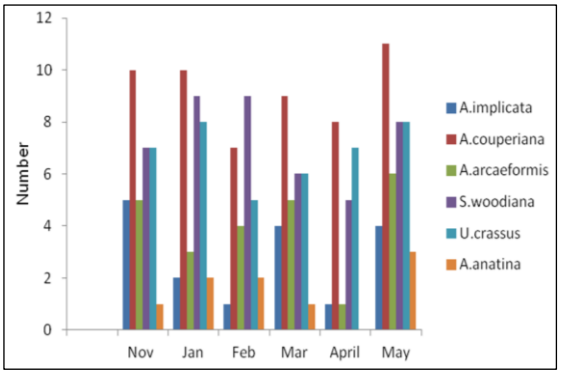

Fig. 6. Monthly species variation of bivalves at Jinnah barrage.

Monthly species variation of bivalves at Dhair Yaru wala

The species named *Anodonta implicata* was found maximum in number each month at Dhair Yaru Wala followed *Strophitus undulates*, *Sinanodonta woodiana*, *Anodonta cygnea* respectively. The species *Lamellidens marginalis* was found least in number. The similar trend of distribution was found throughout the sampling period (Fig. 7) The Fig. 8 reflects that *Anodonta implicata* was leading each

month at River Indus followed by *Strophitus undulatus*, *Anodonta couperiana*, *Anodonta arcaeformis*, *Sinanodonta woodiana* , *Unio crassus* , *Anodonta cygnea*, *Anodonta californiensis*, *Lamellidens marginalis* however *Anodonta anatina* was found least in number with similar trend throughout sampling period.

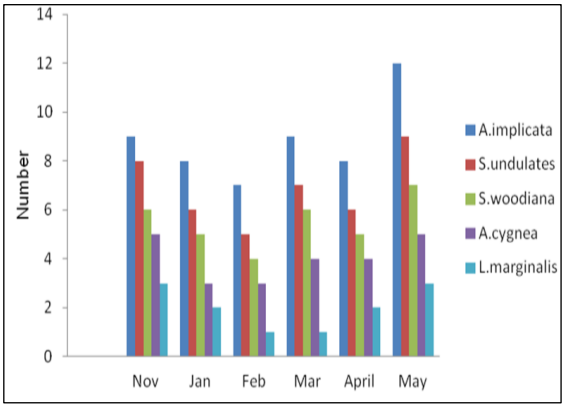

Fig. 7. Monthly species variation of bivalves at Dhair Yaru wala.

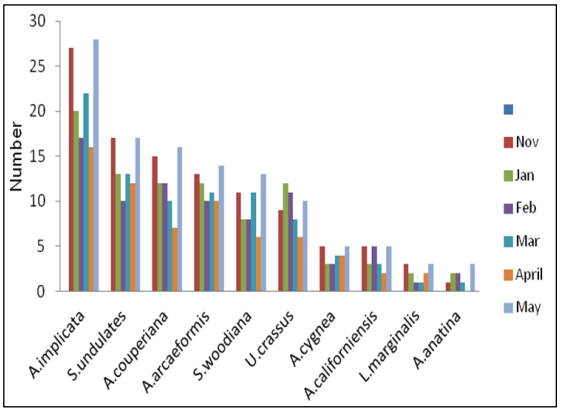

Fig. 8. Monthly Species Variation of Bivalves at River Indus.

Species Diversity Indices for Bivalves at Indus

The application of Shannon wiener index indicated that the species harboured in the Chahshma barrage, Jinnah barrage and Dhair Yaru wala were highly diversified and significant. (J=0.918, J=0.919 &J=0.957 respectively (Table 5-7).

The application of Shannon wiener index (H'=3.006) indicated that the species harboured in the Indus river were highly diversified and significant(J=0.905) (Table 8).

Table 5. Species Diversity Indices for Bivalves at Chashma Barrage.

Species	Chashma	pi	log pi	pi * log pi
Anodonta implicata	31	0.31	-1.68966	-0.52379
Strophitus undulates	23	0.23	-2.12029	-0.48767
Anodonta couperiana	20	0.2	-2.32193	-0.46439
Anodonta arcaeformis	9	0.09	-3.47393	-0.31265
Sinanodonta woodiana	0			0
Unio crassus	5	0.05	-4.32193	-0.2161
Anodonta cygnea	0			0
Anodonta californiensis	12	0.12	-3.05889	-0.36707
Lamellidens marginalis	0			0
Anodonta anatina	0			0

Table 6. Species Diversity Indices for Bivalves at Jinnah barrage.

Species	Jinnah Barrage	pi	log pi	pi * log pi
Anodonta implicata	9	0.09	-3.47393	-0.31265
Strophitus undulates	0	0	0	0
Anodonta couperiana	21	0.21	-2.25154	-0.47282
Anodonta arcaeformis	28	0.28	-1.8365	-0.51422
Sinanodonta woodiana	14	0.14	-2.8365	-0.39711
Unio crassus	24	0.24	-2.05889	-0.49413
Anodonta cygnea	0	0	0	0
Anodonta californiensis	0	0	0	0
Lamellidens marginalis	0	0	0	0
Anodonta anatina	4	0.04	-4.64386	-0.18575
Jinnah Barrage	H'	J	2.377	0.919

Table 7. Species Diversity Indices for Bivalves at Dhair yaru wala.

Species	N	pi	log pi	pi *log pi
Anodonta implicata	33	0.33	-1.59946	-0.52782
Strophitus undulates	23	0.23	-2.12029	-0.48767
Anodonta couperiana	0	0	0	0
Anodonta arcaeformis	0	0	0	0
Sinanodonta woodiana	18	0.18	-2.47393	-0.44531
Unio crassus	0			
Anodonta cygnea	15	0.15	-2.73697	-0.41054
Anodonta californiensis	0	0	0	0
Lamellidens marginalis	11	0.11	-3.18442	-0.35029
Anodonta anatina	0	0	0	
Dhair yaru	H'	J	2.222	0.957

Table 8. Species Diversity Indices for Bivalves at Indus.

Species	n	pi	log pi	pi * log pi
Anodonta implicata	73	0.243333	-2.03899	-0.49616
Strophitus undulates	46	0.153333	-2.70526	-0.41481
Anodonta couperiana	41	0.136667	-2.87127	-0.39241
Anodonta arcaeformis	37	0.123333	-3.01937	-0.37239
Sinanodonta woodiana	32	0.106667	-3.22882	-0.34441
Unio crassus	29	0.096667	-3.37084	-0.32585
Anodonta cygnea	15	0.05	-4.32193	-0.2161
Anodonta californiensis	12	0.04	-4.64386	-0.18575
Lamellidens marginalis	11	0.036667	-4.76939	-0.17488
Anodonta anatina	4	0.013333	-6.22882	-0.08305
Indus	H'	J	3.006	0.905

Discussion

The assessment of occurrence and diversity of freshwater mussels provides a valuable and effective estimation of Indus river biodiversity. As the freshwater mussels of the families Uninodae and Margaretiferidae are the best studied group in the United States of America the collected record is well documented with change in distribution and abundance of many species (Turgeon *et al*., 1988).

In particular three sites (Chashma barrage, Jinnah barrage and Dhair Yaru wala) the species of bivalves are highly diversified which is in contrast to the aquatic biodiversity in UK lowland rivers having low mussels abundance (Aldridge *et al*. 2007).

In Chashma barrage and Dhair Yaru wala the most abundant species was *A.implicata* i.e. 31and 33 specimens respectively, while in Chashma barrage *U.crassus* i.e. 05 specimens and at Dhair Yaru wala *L.marginalis* i.e.11 specimens have low abundance.

In case of Jinnah barrage *A.arcaeformis* was the dominant one i.e. 28 and the *A.anatina* was in the least number i.e.04 individuals . Rest of all the species were equally distributed, in the three selected sites. Freshwater mussels are distributed throughout the world occurring in lotic and lentic system of freshwater (Wachtler & Bauer, 2001, Killeen *et al*. 2004, Aldridge 2007).

The results depicted that fauna of freshwater mussels in all three selected sites were also diversified and distributed. From the selected sites *Anodonta implicata* either with *Strophitus undulatus* or with *Unio crassus* was showing overlapping may be the reflection of different habitats requirement of these species, while uninoids except *A.cygnea* and *A.anatina*as mentioned by Killeen *et al*. 2004, that *A.cygnea* are rarely found in freshwater.

The morphologal characteristical analysis was the traditional basis of identification (Spooner & Vaughn, 2006). At the generic level the higher proportion of (60.66%) with Anodonta, (15.33%) with Strophitus, (9.66%) with unio and (3.66%) with Lamellidens were found, which are supported by the results stating Aonodonta (21.20%), Elliptio (14.49%) and Margeritifera (8.48%) (Curol, Foltz & Brown 2004)

All the studied parameters indicated that the selected three sites (Chashma barrage, Jinnah barrage & Dhair Yaru wala) of the River Indus were highly significant with respect to diversity that is richness and evenness. The present study is helpful for identification of freshwater mussels of river Indus. In the present study 1 family, 4 genera and 10 species were identified and in this oriental region 8 families, 47 genera and 150 species have already been taxonomically characterized. (Bogan 2008).

Though a lot of work has been done on the hydrological and macro benthic faunal aspects on lotic freshwater bodies by earlier workers Dutta *et al*., (2000), but no work has been done on the molluscan diversity Mushtaq (2007) and Sawhney (2008). The total number of freshwater bivalves for Asia is not known although it is expected that Asia, especially South Asia and China and have a high diversity of family Unionoidae, next to central and east North America.

Recent projects are on the evaluation of freshwater biodiversity for some known groups i.e fish or other groups, mostly related to conservation strategies (Revenga and Kura, 2003; Groom bridge and Jenkins, 1998; Lévëque, 2002).

Freshwater molluscs are one of the most diverse and imperiled groups of animals, although not many people other than a few specialists who study the group seem to be aware of their troubles. Malacologists should play active role in conservation, including research, conservation management strategies, and education (Lydread *et al.*, 2004).

Conclusions and recommendations

The study shows that River Indus is resource of diverse freshwater Bivalvia and must be studied further for the exploration of this group of inverteberates which is promising to explore this economically and ecologically important fauna.

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