INTRODUCTION

Mussels (Class Bivalvia, Phylum Mollusca) are ancient in origin and are worldwide in distribution (Graf and Cummings, 2007). Freshwater mussels belong to Order Unionoida are among the most varied familiar and plentiful animals in freshwaters (Cope et al., 2008). They are constituting an important part of aquatic food web (Vaughn et al., 2008), supporting both aquatic ecosystems and their biodiversity (Sharma, 2010). Two species of freshwater mussels, viz. Sinanodota woodiana (Dharya Yaruwala, and Jinnah Barrage) and Lamellidens marginalis (Dharya Yaruwala, have been recently reported from littoral waters of Indus River (Shaifullah et al., 2017). Lamellidens marginalis has been previously reported from Zhob and Jafferabad Districts (Kaker et al., 2017) and Kotri Barrage (Burdì et al., 2009) yet Sinanodota woodiana is not reported from any other region. It appears that the Indus River populations are isolated populations of these species. The present study is based upon the hypothesis that the present samples of these species are distinct isolated ecotypes. The present paper reports ecotype variability based upon morphometric observations on shell size and shape.

原材料和方法

采样和识别：三个地点，即 Jinnah Barrage (32.57° N; 71.30° E), Chasma Barrage (32.434° N; 71.379° E) 和 Dhair Yaruwala (32.409° N; 71.371° E) 被访问 (November, 2011 – May 2012) 和 528 新鲜双壳类样品被手捡从河岸地区被 Indus River (Fig. 1) 服务使用专业的潜水员。样品被装入冰容器，送到实验室，并在 70% 酒精中保存。所有标本被识别到物种水平基于类群的物种概念 (Rao, 1989) 和 Preston (1915). Specimen of Sinanodota woodiana (n 32; Dhair Yaruwala (18) and Jinnah Barrage (14)) and Lamellidens marginalis (n 11; Dhair Yaruwala) were separated, identified, reconfirmed (Daniel L. Graf Carnegie Museum of Natural History) and were subjected to morphometric studies, viz., shell length, shell width and width using a Vernier caliper (minimum count: 0.01 mm) following Guarneri et al. (2014). The mean, standard error of mean and ratios between different variables were calculated using usual statistical techniques following Ludwig et al., 1988.

SOME MORPHOMETRIC RECORDS ON Sinanodonta woodiana AND Lamellidens marginalis (MOLLUSCA: BIVALVIA) FROM CENTRAL REACHES OF INDUS RIVER, PAKISTAN

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Bivalvia has an extremely important position in our ecosystem as biofilters, bioindicators for environmental quality and most of all source of pearls. They play important role in food web. However, the taxonomic work regarding identification of bivalves species is quite scanty due to lack of taxonomic expertise. They play important role in food web. Total 556 specimens were collected from Chashma Barrage, Jinnah Barrage and Dhair Yaruwala (River Indus) for their taxonomic characterization. The identification of the specimens was made on the basis of morphological and morphometric characters using vernier caliper. Identification of the specimens was done by using recent identification keys and diagrammatic description. We found bivalves belonging to 1 family 2 genera and 2 species, Sinanodonta woodiana and Lamellidens marginalis are being reported for the first time from River Indus, Pakistan. Although both species are important for pearl production yet Lamellidens marginalis are edible and of commercial importance. This is a baseline study to get the basic information about the bivalves of River Indus near Chashma Barrage, Jinnah Barrage and Dhair Yaruwala which will be important in various applied fields like pearl culture. Our results reveal the bivalve species in the central reaches of River Indus, Punjab, Pakistan

Keywords: Taxonomy, identification, Dhair Yaruwala, Chashma Barrage, Jinnah Barrage, River Indus.

INTRODUCTION

MATERIALS AND METHODS
RESULTS

The morphometry of the bivalve specimens was carried out and the summary of the data was recorded for length, width and height and their inter-relationship (Table 1).

**Taxonomic characterization of the bivalves on the basis of morphometrics**

**Family Unionidae Fleming, 1928:** All the specimens are freshwater bivalvia belonging to the same family Unionidae. The shell is nacreous, inequilateral, inequivalve. The sizes are usually large but variable in size, thickness and shape. The umbral area is mostly pearly and corrugately sculptured. The hinge plate consists of two cardinal and two posterior lamellar teeth in left valve and single cardinal and single lamellar tooth in right. The ratio between shell length and shell width lies between 14-17mm and the ratio between shell height and shell width ranges from 15mm-19mm. This family is represented by two genera and two species from the Upper River Indus, District Mianwali and is been reported for the first time in Pakistan.

**Sinanodonta woodiana** (Lea, 1834)

**Species description:** There are a number of morphotypes on the basis of the variation in the colouration patterns of the given species that have been shown (Fig. 2 to Fig. 11). The nacre is white and the periostracum is black and white. The teeth and swellings are absent with hinge plate that is uniformly thin (Fig. 2). The shells are transparent with green rays on the periostracum with the dorsal margin (Fig. 3). The shell is thicker with brown to chocolate brown in colour having green tinge in the nacre which is more pronounced at the margins (Fig. 4).

<p>| Table 1. Checklist of the Species of the Class Bivalvia in River Indus Mianwali |
|-----------------|----------------|----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Class</th>
<th>Order</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bivalvia</td>
<td>Unionida</td>
<td>Unionidae</td>
<td>Sinanodonta</td>
<td>Sinanodonta woodiana</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lamellidens</td>
<td>Lamellidens marginalis</td>
</tr>
</tbody>
</table>
Identification of Bivalve Species on the basis of morphological markers

Figure 4. *Sinanodonta woodiana* (Lea, 1834) (Morphotype 3)

Figure 5. *Sinanodonta woodiana* (Lea, 1834) (Morphotype 4)

Figure 6. *Sinanodonta woodiana* (Lea, 1834) (Morphotype 5)

Figure 7. *Sinanodonta woodiana* (Lea, 1834) (Morphotype 6)
The shell is pale and thin with pearly or whitish nacre however the periostracum outside is glossy light brown with concentric growth lines with greenish patterns giving shell an overall yellowish or greenish brown colour (Fig. 5). The shells of the specimens of are fragile and the periostracum is mostly brown with the white or bluish nacre (Fig. 6). The shell is thicker with brown colour having green striations. The shell is pale and thin with pearly or whitish nacre however the periostracum outside is glossy light brown with concentric growth lines with greenish patterns giving shell an overall yellowish or greenish brown colour (Fig. 7). The
shells are transparent with green rays on the periostracum with the dorsal margin (Fig. 8). The shell is smooth and shiny. It is chestnut, dark brown, or black in older individuals. Periostracum is chocolate brown and nacre is orange in the beak cavity and is usually iridescent. The periostracum is from light brown to chocolate brown with a whitish beak. The nacre is greenish at the margins white in the center and brown in the umbo (Fig. 9). The mean length of the *S. woodiana* ranged from least from 61mm to 192mm. The mean height ranged from 40mm to 121mm and the mean width of the shells of *S. woodiana* varied from 24mm to 63mm. The SL/SW ratio ranged from 2.25mm-3.04mm. The SH/SW ranged from 1.56mm-1.92mm. The SL/SH of the shells ranged from 1.37mm-1.62mm. (Table 2).

**Lamellidens marginalis** (Lamarck, 1819)

*Species description:* The color of the periostracum is chocolate brown while the nacre is milky white. The shell is oval in shape, however narrow at the posterior end, (Fig. 11) which is in confirmation with the previous literature (copy right 2016.biologydiscusion.com). While comparing it with the *Lamellidens marginalis* the mean length of the specimen sample from only one station was 90mm with a mean height of 52mm and mean width of 35mm the shell length/ Shell width is similar to the *S. woodiana* however SH/SW is 1.48 and SL/SH is 1.73. The maximum specimen size was found 90 mm in length, 52 mm in height and 35mm in width. (Table 2).

**Table 2. Some morphometric values of two bivalve species from Indus River Mianwali.**

<table>
<thead>
<tr>
<th></th>
<th><em>S. woodiana</em></th>
<th></th>
<th><em>L. marginalis</em></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Coefficient of Variation</td>
<td>Mean</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>142.12</td>
<td>36.99</td>
<td>0.26</td>
<td>90.00</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>93.38</td>
<td>21.80</td>
<td>0.23</td>
<td>52.00</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>51.62</td>
<td>9.02</td>
<td>0.17</td>
<td>35.00</td>
</tr>
<tr>
<td><strong>Shell length/shell width</strong></td>
<td>2.75</td>
<td></td>
<td></td>
<td><strong>Shell height/shell width</strong></td>
</tr>
<tr>
<td><strong>Shell height/shell width</strong></td>
<td>1.52</td>
<td></td>
<td></td>
<td><strong>Shell length/shell height</strong></td>
</tr>
<tr>
<td><strong>Shell height/shell width</strong></td>
<td>1.73</td>
<td></td>
<td></td>
<td><strong>Shell length/shell height</strong></td>
</tr>
</tbody>
</table>

In Jinnah barrage and Chashma Barrage no specimen belonging to species *L. marginalis* was found throughout the six months (Table 3; Fig. 12) showing the area has low species density.

**DISCUSSION**

The shell shapes of the Chinese pond mussel (*Sinanodonta woodiana*) were studied to estimate the morphological difference inside and between two populations of *S. woodiana* using elliptic fourier analysis showing morphological variation among the two populations which might be the result of some fundamental genetic roots (Demayo et al., 2012). The species of *Anodonta (Sinanodonta) woodiana* is generally confused with the *A. arcaeariformis*due to the similarities in the morphological parameters with the periostracum which is from light brown to chocolate brown with a whitish beak. The nacre is greenish at the margins white in the centre and brown in the umbo. The anterior margin is roundly pointed while the posterior margin is rounded. The hinge line is straight with circular striations. The embryonic shell is thinner than at the margins.https://search.yahoo.com/search?p=Anodonta+arcaeformis&fr=yset_widemail_chr_win&type=default

According to USFWS, (2015) the size of the specimens may reach to 300mm.

The *Sinanodonta woodiana* is native to temperate and tropical eastern Asia. This species is currently found in at least fifteen European countries including Romania, Czech Republic, Belgium, Hungary, France, Slovakia, Austria, Poland, Ukraine, Italy, Germany, Serbia, Bulgaria, Moldova, Spain and Sweden as well as in some Indonesian islands (exact location unclear), Dominican Republic, USA (New Jersey), and Costa Rica (Cummings 2011, pers. comm.) and *L. marginalis* has been reported from lower and upper Gangetic plains in India and Bangladesh, Sri Lanka, Myanmar (Rao, 1989; Ramakrishna and Dey 2007) and Terai region of Nepal (Nesemann et al., 2007). The population status of these species has been reported as least concern (Madhavastha et al., 2010).
S. woodiana named as Chinese pond mussel and L. marginalis has been reported for the first time from the three different stations i.e., Dhairyaruwala, Jinnah barrage and Chashma Barrage of the River Indus after revisions in the taxonomy of the previously reported ten species (Shafiullah et al., 2017). L. marginalis has previously been reported from River Indus, Sindh, in fairly good numbers. Total 175 specimens were sampled from Dhairyaru wala out of which only 12 specimens belonged to the L. marginalis, with few numbers in different months, while the rest of the 163 specimens belonged to S. woodiana, showing maximum species density in the months of May, April and March respectively and the results are in accordance with Burdi et al., (2009). The low numbers of L. marginalis in this region might be due to S. woodiana (Lea, 1834) (the Chinese pond mussel) which is a known invasive species of the Unionidae (Lopes-Lima et al., 2017) however in other parts of the South East Asia the population status of this species has been reported as least concern (Madhyastha et al., 2010). S. woodiana may affect native mussel populations, including the negative impact via cross-resistance of host fishes (Sousa et al., 2014; Donrovich et al., 2017). Adult Sinanodonta species effectively compete with indigenous species for food, space, and host fishes. Not only this, they modify natural ecosystems by influencing physical, chemical and biological parameters of the water environment (Bolotov et al., 2016). The members of the genus Lamelledins are of economic importance as they are being used for the pearl culture in Bangladesh, however in Pakistan they are not being harvested and cultured for the human benefit and are reduced in numbers in certain parts.

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Conflict of Interest: The authors declare that there is no conflict of interest.

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