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Research Article

Ecology and species composition of Molluscs in upstream of the Kor River System, with two new records for the Fars Province, Iran

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Abstract

The scientific literature on molluscans taxonomy in Iran goes back to many years ago; however, in some parts of the country like southern areas, it is completely new. In addition, many of the studies have focused on their potential risk as intermediate hosts for parasites, ignoring their specific taxonomic identification or detailed ecology. In this research, molluscan fauna of Jubkhalle River, southern Iran was investigated in five stations during 2015 and 2016 within a span of 13 km. Four species from gastropods including *Physa acuta*, *Planorbis intermixtus*, *Radix persica* and *Galba truncatula* as well as a bivalve species *Pisidium casertanum* were identified. Among them, *R. persica* and *P. casertanum* were new records for the Fars Province. Our results showed consistencies between the number of species present and their environmental settings including total dissolved solids, electrical conductivity, and the water current velocity. Mean annual current velocity was lowest in station 2, having the highest temporal fluctuation, while total dissolved solids drastically increased in lower reach (stations 4 and 5), with the lowest fluctuations.

Keywords: Aquatic invertebrates, conchology, stream ecology, Zagros Mountains.

Introduction

Molluscs are a common group of macrozoobenthic invertebrates in aquatic ecosystems. They are found in shallow water, streams, rivers, ponds and lakes. They have significant functions in food webs and ecosystem equilibrium such as nutrient cycling, biofiltration and storage (Vaughn 2017). However, like many other aquatic organisms, they are threatened by various environmental stresses, including drought, habitat degradation, dam constructions, pollution, channel modification, siltation and introduction of non-indigenous species (Zieritz *et al.* 2018, Williams *et al*. 1992).

Systematic studies of molluscs in Iran have a history older than many other taxa which were begun in early 1863 by the investigation of molluscan fauna of the Caspian Sea (Dybowski 1888). Studies on the molluscan fauna have provided extensive data from many areas of the country including Sistan and Baluchistan Province (Annandale and Prashad 1919; Annandale 1921; Annandale and Rao 1925), the Central Plateau and Mazandaran Province (Biggs 1936, 1937, 1971, Forcart 1935), the Northern and Eastern Iran (Starmühlner 1961, 1965), Tonekabon, Mazandaran Province (Abbaspour *et al.* 2012), Zayanderood River

(Esfahan province) (Nemati-Varnosfaderany *et al*. 2010), Zarrinehrud estuary, west Azerbaijan (Ahmadi *et al.* 2011), and the Dez River, Khuzestan Province (Saba *et al* 2012).

Aquatic gastropods in Fars Province have been investigated quite recently, including species of *Lymnea*, *Physa*, *Sphaerium*, and *Gyraulus* in the Kor river, (Haffar *et al*. 2010). Glöer and Pešić (2009) described the new species *Farsithyra farsensis* from Firouzabad, *Pseudobithynia zagrosia* from Dashte Arzhan, and *Planorbis intermixtus* Mousson, 1874 from Sepidan County (Glöer and Pešić 2010), all from the Fars Province. Newest studies have also addressed several species such as *Melanopsis praemorsa* (the authors believe that it must be *M. buccinoidea* (Olivier 1801)), *M. doriae*, *Physa acuta*, *Lymnaea gedrosiana*, *L. trancatula*, *L. pereger*, *Gyraulus euphraticus* and *Farsithyra farsensis* from Sasan spring, Kazeroon County (Mokhtari *et al.* 2015). Some species of families Lymnaeidae, Physidae, Planorbidae, and Sphaeriidae were reported from Behesht-e Gomshodeh, Marvdasht County as well (Karami *et al*. 2015). Despite, there are still many areas, especially in river reaches lacking any data on their biota.

Material and methods

This survey was carried out in Jubkhalle stream in Sepidan County, Fars Province, south of Iran, inside the mountains of Southern Zagros. Average annual temperature and annual precipitation of the region are 13°C and 289 mm. respectively (Climate Data 2018). This river originates from Chelkalagh, Komehr, Jubkhalle and Kakan Mountains, joining to Margoon stream and then to the Kor River, the largest river in the province. After crossing Marvdasht County and Doroodzan dam, it flows into the Bakhtegan Lake (Fig. 1). Jubkhalle is the main source of irrigation for agriculture and fish farming.

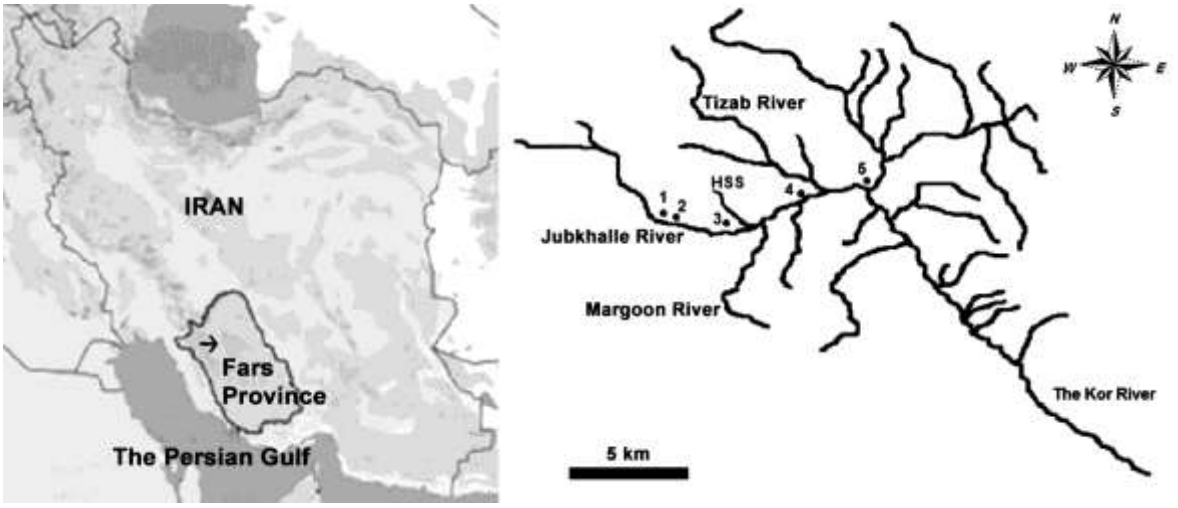

Figure 1. Left: location of the study area in Fars Province, Right: map of the Kor river system showing Jubkhalle River and the sampling sites. HSS: a small but highly saline stream.

Jubkhalle is a permanent, second order river with successive riffles and pools. The streambed has a cover of pebbles, cobbles, and large boulders, with exceptions in bends where small areas of sand and silt formed over cobbles. The silt-sand beds are sometimes mixed with leaf and stick detritus in some bend margins. Small masses of water silk (filamentous charophyte *Spirogyra* sp.) are spread along the river. Occasionally, groups of reeds are grown on riversides, and dispersed small aggregates of aquatic plants are formed close to the margins (Fig. 2).

Stations were selected based on particular river conditions (distance from fish farms, topography, and ease of access) in a total range

of ca. 13 km. The five stations included station 1 before a fish farm complex (30°32'50.3"N 51°53'42.7"E), station 2 after the fish farm (30°32'51.2"N 51°54'00.2"E), station 3 in 3 km from the fish farm (30°33'04.0"N 51°54'39.6"E), station 4 in 7.5 km from the fish farm (30°34'54.1"N 51°58'10.2"E), and station 5 in 12 km from the fish farm (30°35'03.8"N 52°01'09.3"E) (Fig. 1).

Figure 2. Views of station 2 (left) and station 3 (right).

Sampling was performed six times (bimonthly) from May 2015 to March 2016. Samples were collected in the morning (0800-1200) using a Surber sampler with three replications at each station. Specimens were fixed immediately in 75% ethanol. Samples were subsequently identified under a stereomicroscope. Some of the major environmental factors were measured *in situ* including air and water temperature, pH (HANA-HI 1281), dissolved oxygen (Hach HQ40d Multimeter), current velocity (the cross-sectional method by multiplying a cross-sectional area of the stream by the velocity of the water), and electrical conductivity (HANNA HI2300-01). Some others were measured using water samples in the laboratory (including total suspended solids (TSS), biochemical and chemical oxygen demand (BOD and COD), total dissolved solids (TDS), concentration of phosphate ion [PO_4], nitrite [NO_2], nitrate [NO_3], and ammonia [NH_4]). Methods of APHA (1999) were followed for all measurements. Data were statistically analyzed with ANOVA in IBM SPSS Statistics 23.

Result

The highest and the lowest recorded air temperature in the investigation period was 32°C and 8°C. Mean water temperature was 14.5°C, with maximum and minimum of 25°C and 8°C. Mean current velocity was 0.5 m/s, with the minimum (0.4 m/s) in station 2 and maximum (0.6 m/s) in station 3, while station 3 and 4 showed a rapid increase in total dissolved solids to 814 and 902 ppm, respectively. Some

measured physical and chemical factors of the river are presented in Table 1.

Table 1. The annual mean of some physical and chemical factors in Jubkhalle River from May 2015 to March 2016.

	Station 1	Station 2	Station 3	Station 4	Station 5
DO (% sat.)	112.1±2.4**a**	101.7±1.1**b**	115.3±4.6**a**	109.7±2.7**ab**	107.9± 2.3**ab**
Water T (°C)	13.7±1.0	13.7±1.0	14.4±1.6	15.9±3.0	15.1±1.0
pH	8.36±0.05	8.31±0.05	8.53±0.17	8.53±0.11	8.19±.33
TSS (ppm)	5.90±1.62	6.90±1.79	6.93±1.81	4.90±1.55	5.50±1.43
Current velocity (m/s)	0.54±.0.17	0.38±0.11	0.62±0/08	0.48±.0.09	0.46±0.08
BOD (ppm)	1.13±0.15**b**	1.32±0.19**b**	2.05±.0.34**a**	1.25±.0.10**b**	1.16±0.25**b**
COD (ppm)	7.62±.0.25	8.42±0.12	8.33±0.76	7.90±0.39	8.22±.74
EC (µs/cm)	354±18**b**	337±19**b**	343±23**b**	1251±70**a**	1384±81a
TDS (ppm)	228±12**b**	217±12**b**	221±15**b**	814±48**a**	902±57**a**
[PO4] (ppm)	0.203±0.049	0.250±0.062	0.245±0.073	0.148+0.43	0.138±0.033
[NO2] (ppm)	0.007±0.001**bc**	0.006±0.001**c**	0.013±0.003**ab**	0.011±.0.001**abc**	0.014±0.003**a**
[NO3] (ppm)	1.2±0.2	1.5±0.2	1.6±0.2	1.1±0.2	1.2±0.4
[NH3] (ppm)	0.062±0.019**b**	0.177±0.047**a**	0.197±0.023**a**	0.128±0.038**ab**	0.014±0.050**b**

Different letters show significant differences within the same row ($P < 0.05$)

Several invertebrate species belonging to diverse taxa among insects (Ephemeroptera, Coleoptera, Plecoptera, Trichoptera, Diptera, Hemiptera, and Odonata), flatworms (Tricladida), crustaceans (Amphipoda), as well as gastropod and bivalve Molluscs, were found in the river. Among the gastropod specimens, five species were identified, belonging to three families and five genera. These included *Physa acuta* (Draparnaud 1805), *Planorbis intermixtus* (Mousson 1874), *Radix persica* (Issel 1865), *Galba truncatula* (Müller 1774), and *Pisidium casertanum* (Poli 1791).

However, this survey showed that the assemblages of taxa altered toward downstream. In station 1, before the river enters a trout culture complex, we found one species, *G. truncatula*, while after an outflow of the trout culture complex, in station 2, ca. 200 m from the station 1, all other species were present except *G. truncatula*. In station 3, *G. truncatula* and *Physa acuta* were observed. No gastropod was found in station 4, but *P. acuta* was recorded again in station 5 (Fig. 3). Due to the shortage of mollusc samples, we were not able to perform correlation statistics. However, regarding the fact that the distribution of these species was very distinctive among five stations (Fig. 3), it seems that the data are showing consistencies between the ecology and the distribution of molluscs.

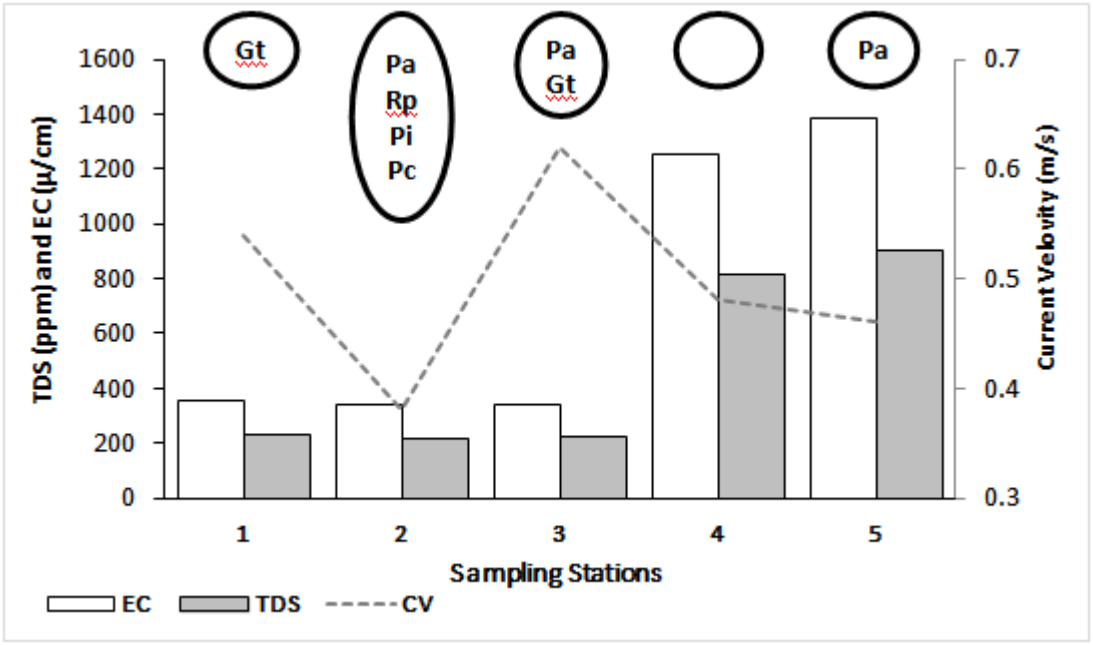

Figure 3. Species composition of Molluscs in five stations along the Jubkhalle stream and changes of water current velocity (CV), electrical conductivity, and total dissolved solids. Pa: *Physa acuta*, Rp: *Radix persica*, Gt: *Galba truncatula*, Pi: *Planorbis intermixtus*, Pc: *Pisidium casertanum*.

Systematics

Five molluscan species have been identified in the Jubkhalle River, including four gastropods *Physa acuta, Planorbis intermixtus, Radix persica and Galba truncatula* and the bivalve *Pisidium casertanum*. Taxonomic classification and a short description of key morphological characters used in identification are listed below.

Class Gastropoda Cuvier, 1795
Superorder Hygrophila Férussac, 1822
Superfamily Lymnaeoidea Rafinesque, 1815
Family Lymnaeidae Rafinesque, 1815
Genus *Radix* Montfort, 1810
***Radix persica* (Issel 1865) (Fig. 4.1)**

Synonymized names: *Limnaea auricularia* var. *persica*, *Lymnaea persica*
Material: 3 specimens, Jubkhalle River, Sepidan County, Fars Province, Iran; station 2 (30°32'51"N, 51°54'00"E), collector: S. Yaripour, March 2015; FAIC 121002.
Description: A great intraspecific variety is seen in the shape of the shell in many species of this genus, so shell morphology is not a suitable character for recognizing among *Radix* species, and application of molecular techniques with topotypes of the species is necessary (Glöer and Pešić 2012).
Shell dimensions: Shell length (SW: 8.13 ± 2.2), shell greatest width (SL: 5.0 ± 1.6), aperture height (AH: 5.7 ± 1.8), aperture width (AW: 3.4±1.0).

Class Gastropoda Cuvier, 1795
Superorder Hygrophila Férussac, 1822
Superfamily Lymnaeoidea Rafinesque, 1815
Family Physidae Fitzinger, 1833
Genus *Physa* Haldeman, 1843
***Physa acuta* Draparnaud, 1805 (Fig. 4.2)**

Material: 16 specimens, Jubkhalle River, Sepidan County, Fars Province, Iran; stations 2 (30°32'51"N, 51°54'00"E), 3 (30°33'04"N, 51°54'39"E) and 5 (30°35'03"N, 52°01'09"E); collector: S. Yaripour, March 2015; FAIC 121002, FAIC 121003, FAIC 121005.
Description: The shell of this species is medium sized, sinistral, and glossy with a sharp apex (Mansoorian 2001).
Dimensions: Shell length (Sl: 7.2± 2.6), shell greatest width (SW: 4.2± 1.7), aperture height (AH: 5.1± 1.9), aperture width (AW: 2.3± 0.9)

Class Gastropoda Cuvier, 1795
Superorder Hygrophila Férussac, 1822

Superfamily Lymnaeidae Rafinesque, 1815
Family Lymnaeidae Rafinesque, 1815
Genus *Galba* Schrank, 1803
***Galba truncatula* (Müller 1774) (Fig. 4.3)**

Synonymized name: *Lymnaea truncatula*
Material**:** 2 specimens, Jubkhalle River, Sepidan County, Fars Province, Iran; station 1 (30°32'50"N, 51°53'42"E) and 3 (30°33'04"N, 51°54'39"E), collector: S. Yaripour, March 2015; FAIC 121001, FAIC 121003.
Description: This species has a dextral shell, with deep suture, a blunt apex and 5–6 convex and stepped whorls, and folded columella.
Shell dimensions: Shell length (SW: 3.6± 0.8), shell greatest width (SL: 2.1± 0.3), aperture height (AH: 1.8± 0.2), aperture width (AW: 1.1± 0.1).
Class Gastropoda Cuvier, 1795
Superorder Hygrophila Férussac, 1822
Superfamily Lymnaeoidea Rafinesque, 1815
Family Planorbidae Rafinesque, 1815
Genus *Planorbis* O.F. Müller, 1774
***Planorbis intermixtus* Mousson, 1874 (Fig. 4.4)**

Synonymized names: *P. planorbis*, *P. persicus*, *P. subangulatus*, *Anisus* (*Gyraulus*) *intermixtus*, *P. planorbis submarginatus*
Material: Single specimen (partially damaged), Jubkhalle River, Sepidan County, Fars Province, Iran; station 1 (30°32'50"N, 51°53'42"E), collector: S. Yaripour, March 2015; FAIC 121001.
Dimensions: Shell width: 4 mm, shell height: 2.0 mm
Description: Shell diameters ca. 20 mm, shell height ca. 3 mm. Adult shells have 5–6 flat whorls, sometimes with a lateral carination. *Planorbis atticus*, *P. planorbis* and *P. intermixtus* may look morphologically similar, but the shell size combined with 23-35 prostate diverticules discriminate *P. intermixtus* from other *Planorbis* species (Glöer and Pešic 2010).

Class Bivalvia Linnaeus, 1758
Superorder Imparidentia Bieler, P. M. Mikkelsen & Giribet, 2014
Superfamily Sphaerioidea Deshayes, 1855 (1820)
Family Sphaeriidae Deshayes, 1855 (1820)
Genus Pisidium C. Pfeiffer, 1821
***Pisidium casertanum* (Poli 1791) (Fig. 4.5)**

Material: 4 specimens, Jubkhalle River, Sepidan County, Fars Province, Iran; station 2 (30°32'51"N 51°54'00"E), collector: S. Yaripour, March 2015; FAIC 121002.
Description: This species has generally rounded shell. The animal is whitish-grayish and slightly transparent, the syphon is subconical, and the foot is not very long. Shell dimensions: Shell length (Sl: 3.7± 0.6), shell height (Sh: 3.2± 0.5).

Figure 4. Photographs of the five molluscan species in Jubkhalle, the Kor River, Fars Province. 1: *Radix persica*, 2: *Physa acuta*, 3: *Galba truncatula*, 4: *Planorbis intermixtus*, 5: *Pisidium casertanum*. Scales represents 1 mm of length. (Photographs were prepared by Dr Peter Glöer)

Discussion

Radix persica was reported from Markazi Province (Glöer and Pešić 2012), *Limnaea auricularia var. persica* from the Kerman (Issel 1865, Martens 1874) and Sistan va Baluchestan Province (Annandale and Prashad 1919), and as *Lymnaea persica*, from Esfahan Province (Biggs 1937). It is the first record of this species from the Fars Province. We found this species in station two in the Spring with Mean temperature of 13.5°C, pH of 8.2, and dissolved oxygen of 8.39 mg/L. Species of *Radix* have been reported as the most sensitive taxa to commonly used pesticides, showing populations decrease after pesticide implementation, with much slower recovery of their density compared to other macroinvertebrate species (Hasenbein *et al.* 2016).

The invasive species *Physa acuta* have previously reported from many places in Khuzestan Province (Mansoorian 2000, Mowlavi *et al.* 2009, Saba *et al*. 2012) as well as The Shadegan Wetland (Karimi *et al*. 2004), Mazandaran Province in Babolrud River (Ahmadi *et al*. 2004), Sistan va Baluchestan Province (Mansourian 2000), and Fars Province (Mokhtari *et al*. 2015). Species of the family Physidae are normally found in ponds, wetlands, eutrophic streams, springs, and temporary aquatic habitats (Strong *et al*. 2008). High reproduction rates, high compatibility, and high passive dispersal capacities have been contributed to their invasive global distribution (Seelan *et al*. 2013). Individuals of *P. acuta* can bury themselves in mud, in which they are able to survive dry seasons and be transported by off-road vehicles for long distances (Banha *et al*. 2014).

Galba truncatula is considered as a European species, spread to other continents (Mas-Coma *et al.* 2005). In Iran, it was reported from the provinces of Mazandaran (Forcart 1935), Kerman (Starmühlner and Edlauer 1957, Biggs 1937), Tehran (Starmühlner and Edlauer 1957), Isfahan Biggs (1937), Gilan, Mazandaran and Lorestan (Mansoorian 2000), Khuzestan (Mansoorian 2001; Chu *et al*. 1968; Massoud and Hedayeti-Far 1979), Semnan and Hormozgan (Starmühlner 1961, 1965), Khorasan (Glöer and Pešić 2012), Sistan va Baluchestan (Annandale and Prashad 1919), and generally from the Caspian Sea, North of Iran (Eliazian *et al*. 1979).

Galba truncatula is an intermediate host of the liver fluke *Fasciola hepatica*, therefore more researches had been devoted to the epidemiology of the related disease, compared to its taxonomy and ecology. We found *G. truncatula* in station one and three with water mean temperature of 14°C, the width of 10 m and depths of 27.7 cm. The highest recorded water temperature was 19°C. Kendall (1953) reported that sustained temperatures much above 20°C were unfavorable and 25°C was significantly harmful. De Kock *et al* (2003) collected most samples in habitats with slow-flowing water with a mean annual air temperature of 10–20°C and muddy substratum. They concluded that temperature and types of water body have significant roles in the presence of *G. truncatula* in the area. In Jubkhalle, flow rate and annual air temperature (Means of stations 1 and 3) were recorded 0.6 m/s and 19°C respectively, but the substratum was composed of gravels in various sizes and a variety of fine sand on river corners.

Planorbis intermixtus was reported from Turkey, N India and different regions of Iran. In Iran, it has been found to be distributed in provinces of Mazandaran, Markazi, Khorasan, and Fars (Glöer and Pešić 2012). This species was reported also by misidentifications as the synonym *P. planorbis* from Northern Iran (Mansoorian 2000), Mazandaran (Eliazian *et al*. 1979, Mansoorian 2000), Fars (Forcart 1935, Starmühlner and Edlauer 1957), and Khuzestan Provinces (Starmühlner and Edlauer 1957, Biggs 1971); as the synonyms *P. persicus* and *P. subangulatus* from Yazd Province (Biggs 1937, 1971, Starmühlner and Edlauer 1957); and as the synonym *Anisus* (*Gyraulus*) *intermixtus* from the Gilan (Starmühlner and Edlauer 1957) and Markazi Provinces (Chu *et al*. 1968, Massoud

and Hedayeti-Far 1979, Mansoorian 2001, Glöer and Pešić 2010).

Like all planorbids, *Planorbis intermixtus* live in streams, rivers, springs, lakes and temporary or permanent ponds (Strong *et al*. 2008) with a high preference for rock type substratum Dussart (1979). In this survey, it was found in parts of the reaches in which the mean depth was around 33 cm, with the deepest area of 70 cm. Mean river width was 8.6 m, with the minimum width in December (7 m) and the maximum in April (10 m).

Pisidium casertanum has a worldwide distribution except in Antarctica (Bespalaya *et al.* 2015). Although *Pisidium* has a wide distribution in Iran, they were identified to the level of genus and information on the distribution of species is not available. Accordingly, *Pisidium* sp. has been so far reported from Gilan, West and East Azarbaijan, Markazi, Zanjan, Qazvin, Hamedan, Kermanshah, Kurdistan, Esfahan, Chaharmahal va Bakhtiari, Khorasan Razavi, North and South Khorasan, and Semnan Provinces (Samayee and Mansoorian 2012).

This species has been reported from ephemeral ponds to large lakes (Bespalaya *et al.* 2015). Bivalve Molluscs are known to be sensitive to water quality, but members of the genus *Pisidium* can tolerate greater nutrient concentrations, so are used as bioindicators of poor water quality. The abundance of *Pisidium* sp. during rainy season increases, and they occupy sediments; therefore, an increase of water velocity may not be an important factor influencing its occurrence and distribution (Martins-Silva and Barros 2001). They live deep in mud, fine sediments, organic matter and turbulent waters (Taybi *et al*. 2017). They can tolerate different salinities and are fairly tolerant of pollution (Kuiper and Wolff 1970). The water temperature recorded in our research was 13.5°C, which lies inside the reported range for *P. casertanum* (5.8 °C to 15°C) (Burky *et al*. 1981).

Conclusion

This investigation revealed the occurrence of five molluscan species in the Jubkhalle River, upstream of the Kor River, in the Southern Zagros. These species included four gastropods *Physa acuta, Planorbis intermixtus, Radix persica and Galba truncatula* and the bivalve *Pisidium casertanum*; among them, *R. persica* and *P. casertanum* have not been previously recorded from the region.

Species composition of the molluscan fauna differed in different sections of the river. The highest diversity was seen in station 2, where the outflow of a trout culture complex enters the stream. Mean current velocity in this locality was the minimum, which acts in favour of benthic invertebrates. Additionally, a high amount of suspended solids produced by the ordinary removal of fish faeces and uneaten fish food makes this place a suitable environment with abundant resources to host larger populations. On the other hand, no mollusc species was found in station 4. A drastic increase of dissolved ions was measured in this station, obviously brought by a small hypersaline spring discharging to the river. After 4.5 kilometres, *Physa acuta*, the most widespread species in the river appeared in station 5 again.

These findings illustrate the importance of ecological data in understanding and proper management of riverine environments in the fragile situation of the current severe drought mixed with non- or poorly assessed human exploitations. Similar investigations in downstream of the Kor River will provide us with a better image of such consequences in the catchments area as a whole.

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