

Rotifers of southwest Iran: a faunistic and biogeographical study

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Abstract: The fauna of freshwater rotifers from Khuzestan Province (Southwest Iran) was expected to be different from that of the rest of Iran because of its geographical position, past geological events, climatic conditions, and similarities to neighboring zoogeographical areas. To test this hypothesis, we first had to determine the rotifer fauna of Khuzestan and then compare it with the results of surveys from other parts of Iran as well as with those from neighboring regions. Samples were collected from 10 sites throughout the province from May 2009 to April 2010. During the study, 66 species were identified, mostly with distribution in tropical and subtropical areas, from which 21 species are new to Iranian fauna. Surprisingly, one of the species, *Colurella sanoamuangae*, is not only new to the Iranian fauna, but also to the Palearctic region. Furthermore, another species, *Lecane inconspicua*, is, for the first time, reported outside the Arabian Plate. Comparisons among the rotifer fauna of Khuzestan, the rest Iran, and the Palearctic, Afrotropical, and Oriental regions, using the Sørensen similarity index, revealed considerable similarities between Khuzestan's fauna and those of the Afrotropical and Oriental regions.

Key words: Freshwater fauna, biodiversity, Rotifera, Palearctic, Oriental, Khuzestan Province

1. Introduction

Rotifers are among the most important aquatic organisms occurring in almost all aquatic ecosystems around the world. Rotifers, together with copepods and cladocerans, are considered as major elements of freshwater ecosystems (Kuczynska-Kippen, 2005; Segers, 2008). Beyond their use as live feed in aquaculture, rotifers have been successfully utilized in many different applied roles in ecology, from bioindication to evaluation of water quality and examining the trophic status of different lakes (Haberman, 1998; Marneffe et al., 1998).

In adjacent counties, considerable studies on rotifers have only been carried out in Turkey (Dumont and De Ridder, 1987; Segers et al., 1992; Altındağ and Yiğit, 2001; Kaya and Altındağ, 2007a, 2007b, 2010; Ustaoglu et al., 2012). On this side of the border in Iran, however, little attention has been paid to the diversity of rotifer fauna, in spite of their great numbers, high diversity, and wide distribution in freshwater ecosystems. Tschugunoff (1921, as cited in Haberman and Sudzuki, 1998) studied the rotifer fauna of the Caspian Sea and reported *Brachionus rotundiformis*. Löffler (1959, 1961), Brishtain et al. (1968), and Ruttner-Kolisko (1971, as cited in Hakimzadeh Khoei et al., 2011) were among the first foreigners working on the rotifer fauna of Iran's freshwater systems. Rotifers had not been studied

here for a long time when, in 2007, in a series of studies at the University of Tehran, interest was renewed in these animals (thesis and reports, e.g., Hakimzadeh Khoei, 2007; Kordbacheh, 2010). Parts of those studies were later published (Hakimzadeh Khoei et al., 2011; Kordbacheh and Rahimian, 2012). In recent years, however, more studies have been dedicated to the diversity of rotifers from different regions of Iran (Malekzadeh Viayeh, 2010; Khaleqsefat et al., 2011), which will eventually result in a complete checklist for the rotifers of Iran. Furthermore, some studies have also been carried out on the ecological aspects of rotifers in Iran (Shayestehfar et al., 2008; Shayestehfar and Abdovis, 2011; Malekzadeh Viayeh and Špoljar, 2012).

Until the present study, 156 rotifer species had been recorded from different parts of Iran. The present study was designed to fill in some of the gaps in our knowledge on rotifer fauna of Iran and to analyze the geographical data of rotifer records from this area. Given the location of the study on the corner of the Palearctic, we also wanted to understand the influence of neighboring zoogeographical regions on both Khuzestan and the rest of Iran, i.e. the Palearctic.

Khuzestan Province, our study area, is situated in the subtropical zone of the southwest corner of Iran (Figure 1) where the province and its freshwater systems, which

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all empty into the Persian Gulf, are isolated from the rest of the country by the high rising Zagros Mountain chain. The rotifer fauna of this province had not been previously studied, so for the first step we turned our attention to the subclass Monogononta, which, with more than 1440 species, is the largest subclass of the phylum Rotifera. This subclass contains widely diverse forms including benthic, pelagic, and sessile species in about 95 genera worldwide (Wallace and Snell, 2001; Segers, 2007). Monogonont rotifers occur in diverse ranges of macro- and microhabitats, from the open waters of lakes to habitats in the interstitial waters, and even in minute water droplets on plants (phytotelmata) or empty gastropod shells (Segers, 2004).

2. Materials and methods

Using a plankton net with a 40- μ m mesh size, we collected rotifer specimens from 10 different stations, including rivers, channels, reservoir, lagoons, pools, and swamps, from May 2009 to April 2010. For each sampling, the general characteristics of the sampling stations, including water turbidity, vegetation, and temperature (Table 1), were recorded. Specimen samples were fixed in a 4% formaldehyde solution immediately after collection. Specimens were studied under stereo and compound-light microscopes. Detailed morphology of external and internal features, including trophi, the key characteristics in identification and taxonomy of rotifers, were studied. Trophi were prepared following the method of De Smet (1998). Specimens were identified using the taxonomic keys of Koste (1978), Koste and Shiel (1987, 1989a, 1989b), Shiel and Koste (1993), and Segers (1995). Drawings and microphotographs were taken using a drawing tube on a compound light microscope and a digital camera mounted on an Imaging Axioplan 2 Zeiss microscope, respectively.

Some specimens were destroyed during the identification procedures and the rest were deposited at the Zoological Museum of the University of Tehran (ZUTC) with their catalog numbers provided in Table 2.

2.1. Study area

The province of Khuzestan, located in the southwest of Iran, covers an area of 63,238 km² in a subtropical zone. Khuzestan Province was selected as the study area because: (1) this area, in its north and northeast parts, is covered by mountains where numerous and diverse freshwater systems originate; (2) rotifer fauna from this area had not been studied before; and (3) being situated in the southwest of Iran, the area acts as a corridor between 2 major zoogeographical regions, the Palearctic and the Ethiopian, and it also connects the subtropical areas of the Ethiopian with those of the subcontinent and the Oriental. Most of the sampling stations were scattered along the 4 main rivers flowing in the area, Karun, Karkhe, Dez, and Jarahi-Maroun (Figure 1). Karun, Karkhe, and Jarahi are 3 large, permanent rivers flowing across the entire territory, from north to south. The Dez, on the other hand, joins the Karun River near the province's capital, Ahwaz. Karun, Iran's largest river (850 km) originates from the Zagros Mountain chain and drains into the Persian Gulf in this province. The other 3 rivers also have their origins in the Zagros (Figure 1).

In addition to those lotic stations, 5 lentic habitats also were sampled for rotifers, including Dez Dam Lake, Bagher pond, Yaqub marsh, Bamdezh, and Shadegan Lagoon. The Dez Dam, with a reservoir of about 3340 $\times$ 10⁶ m³, is located southeast of Dezful. Both Bagher pond and Yaqub marsh are relatively small bodies of water, located in the Dez protected area, and one of them, Yaqub, is well vegetated.

Table 1. Monthly temperatures at different sampling sites (°C).

Stations	May	Jul	Sep	Dec	Feb	Apr
Karkhe	21.5	23.4	26.4	18.1	15.9	20.8
Dez Dam	20.3	30.8	29.2	21.2	15.5	19.9
Dez	21	31.5	28.2	21.4	14.8	21.5
Bagher	24.2	32	27.2	17	13.8	23.8
Yaqub	30.7	34.5	32	18.5	19.1	29.3
Bamdezh	21.9	34	30	15.8	14.5	22.5
Karun	23.2	32.5	27.5	16.7	13.8	23.4
Shadegan (middle part)	25.2	27.5	30.5	17.9	13.8	25.8
Shadegan (southern part)	28.2	30.5	27.7	17.4	15.2	27.1
Jarahi	28.8	32	31	17.5	16.6	27.8

Table 2. List of identified rotifers recorded from Khuzestan Province and corresponding ZUTC catalog numbers. Only those taxa identified to the specific level are listed.

Species	ZUTC
Phylum: Rotifera	
Class: Eurotatoria	
Subclass: Monogononta	
Order: Ploima	
Family: Asplanchnidae	
<i>Asplanchna brightwellii</i> Gosse, 1850	Rot. 1112
<i>Asplanchna priodonta</i> Gosse 1850kmm	Rot. 1075, 1106, 1107, 1113, 1114, 1117
Family: Brachionidae	
<i>Brachionus angularis</i> Gosse, 1851	Rot. 1051
<i>Brachionus calyciflorus</i> Pallas, 1766	Rot. 1049, 1050, 1054
<i>Brachionus diversicornis</i> (Daday, 1883)	Rot. 1047, 1048
<i>Brachionus</i> cf. <i>plicatilis plicatilis</i> Müller, 1786	Rot. 1055
<i>Brachionus quadridentatus quadridentatus</i> Hermann, 1783	Rot. 1057, 1069
<i>Brachionus</i> cf. <i>rotundiformis</i> Tschugunoff, 1921	Rot. 1056
<i>Brachionus urceolaris urceolaris</i> Müller, 1773	Rot. 1052, 1053
<i>Keratella cochlearis cochlearis</i> (Gosse, 1851)	Rot. 1060
<i>Keratella tecta</i> (Gosse, 1851)*	Rot. 1061
<i>Keratella quadrata quadrata</i> (Muller, 1786)	
<i>Keratella tropica</i> (Apstein, 1907)	Rot. 1058, 1059
<i>Notholca salina salina</i> Focke, 1961	Rot. 1070
Family: Dicranophoridae	
<i>Aspelta angusta</i> Harring & Myers, 1928*	Rot. 1118
<i>Dicranophoroides caudatus</i> (Ehrenberg, 1834)	Rot. 1115
<i>Enicentrum putorius</i> Wulfert, 1936	Rot. 1111
<i>Paradicranophorus aculeatus</i> (Neiswestnowa-Shadina, 1935)*	Rot. 1119
Family: Euchlanidae	
<i>Euchlanis dilatata dilatata</i> Ehrenberg, 1832	Rot. 1062
<i>Euchlanis lyra</i> Hudson, 1886*	
<i>Tripleuchlanis plicata</i> (Levander, 1894)	Rot. 1063, 1064
Family: Lecanidae	
<i>Lecane aculeata</i> (Jakubski, 1912) *	Rot. 1093
<i>Lecane bifastigata</i> Hauer, 1938*	Rot. 1100
<i>Lecane bulla bulla</i> (Gosse, 1851)	Rot. 1094, 1095
<i>Lecane closteroerca</i> (Schmarda, 1859)	Rot. 1104
<i>Lecane grandis</i> (Murray, 1913)	Rot. 1092
<i>Lecane hamata</i> (Stokes, 1896)	Rot. 1103
<i>Lecane inconspicua</i> Segers & Dumont, 1993*	Rot. 1098
<i>Lecane lamellata</i> (Daddy, 1893)	
<i>Lecane luna</i> (Müller, 1776)	Rot. 1099
<i>Lecane lunaris</i> (Ehrenberg, 1832)	Rot. 1102
<i>Lecane papuana</i> (Murray, 1913)	

Table 2. (Continued).

Species	ZUTC
<i>Lecane plesia</i> Myers, 1936*	Rot. 1091
<i>Lecane punctata</i> (Murray, 1913)	Rot. 1096, 1097
<i>Lecane pyriformis</i> (Daday, 1905)*	Rot. 1101
<i>Lecane scutata</i> (Harring & Myers, 1926)	
<i>Lecane stenroosi</i> (Meissner, 1908) *	Rot. 1089, 1090
<i>Lecane thalera</i> (Harring & Myers, 1926)	Rot. 1087, 1088
Family: Lepadellidae	
<i>Colurella adriatica</i> Ehrenberg, 1831	Rot. 1078
<i>Colurella sanoamuangae</i> Chittapun, Pholpunthin & Segers, 1999**	Rot. 1076
<i>Colurella uncinata. bicuspidata</i> (Ehrenberg, 1832)	Rot. 1077
<i>Lepadella quadricarinata</i> (Stenroos, 1898)	Rot. 1079
<i>Lepadella patella patella</i> (Müller, 1786)	Rot. 1080, 1082
<i>Squatinella lamellaris</i> (Müller, 1786)*	
<i>Squatinella rostrum</i> (Schmarda, 1846)	Rot. 1081
Family: Lindiidae	
<i>Lindia torulosa</i> Dujardin, 1841*	
Family: Mytilinidae	
<i>Lophocharis oxysternon</i> (Gosse, 1851)*	Rot. 1084, 1085, 1086
<i>Lophocharis salpina</i> (Ehrenberg, 1834)	Rot. 1083
<i>Mytilina ventralis brevispina</i> (Ehrenberg, 1830)*	Rot. 1065
Family: Notommatidae	
<i>Cephalodella major</i> (Zavadowsky, 1926)	
<i>Cephalodella forficula</i> (Ehrenberg, 1830)	
<i>Cephalodella gibba</i> (Ehrenberg, 1830)	Rot. 1116
<i>Eosphora cf. anthadis</i> Harring & Myers, 1922*	Rot. 1110
<i>Pleurotrocha atlantica</i> Myers, 1936*	
<i>Pleurotrocha petromyzon</i> (Ehrenberg, 1830)	
<i>Notommata copeus</i> Ehrenberg, 1834	Rot. 1109
<i>Notommata tripus</i> Ehrenberg, 1838*	Rot. 1120
<i>Resticula melandocus</i> (Gosse, 1887)	
<i>Taphrocampa annulosa</i> Gosse, 1851*	
Family: Proalidae	
<i>Proales theodora</i> (Gosse, 1887)	Rot. 1108
Family: Trichocercidae	
<i>Trichocerca porcellus</i> (Gosse, 1851)	
<i>Trichocerca pusilla</i> (Jennings, 1903)	Rot. 1105
Family: Trichotriidae	
<i>Macrochaetus altamirai</i> (Arévalo, 1918)*	Rot. 1074
<i>Macrochaetus collinsii</i> (Gosse, 1867) *	Rot. 1071, 1072, 1073
<i>Trichotria pocillum</i> (Müller, 1776)	Rot. 1066
<i>Trichotria tetractis similis</i> (Stenroos, 1898)	Rot. 1067, 1068

*: New records for Iran.

**: New record for Iran and Palearctic.

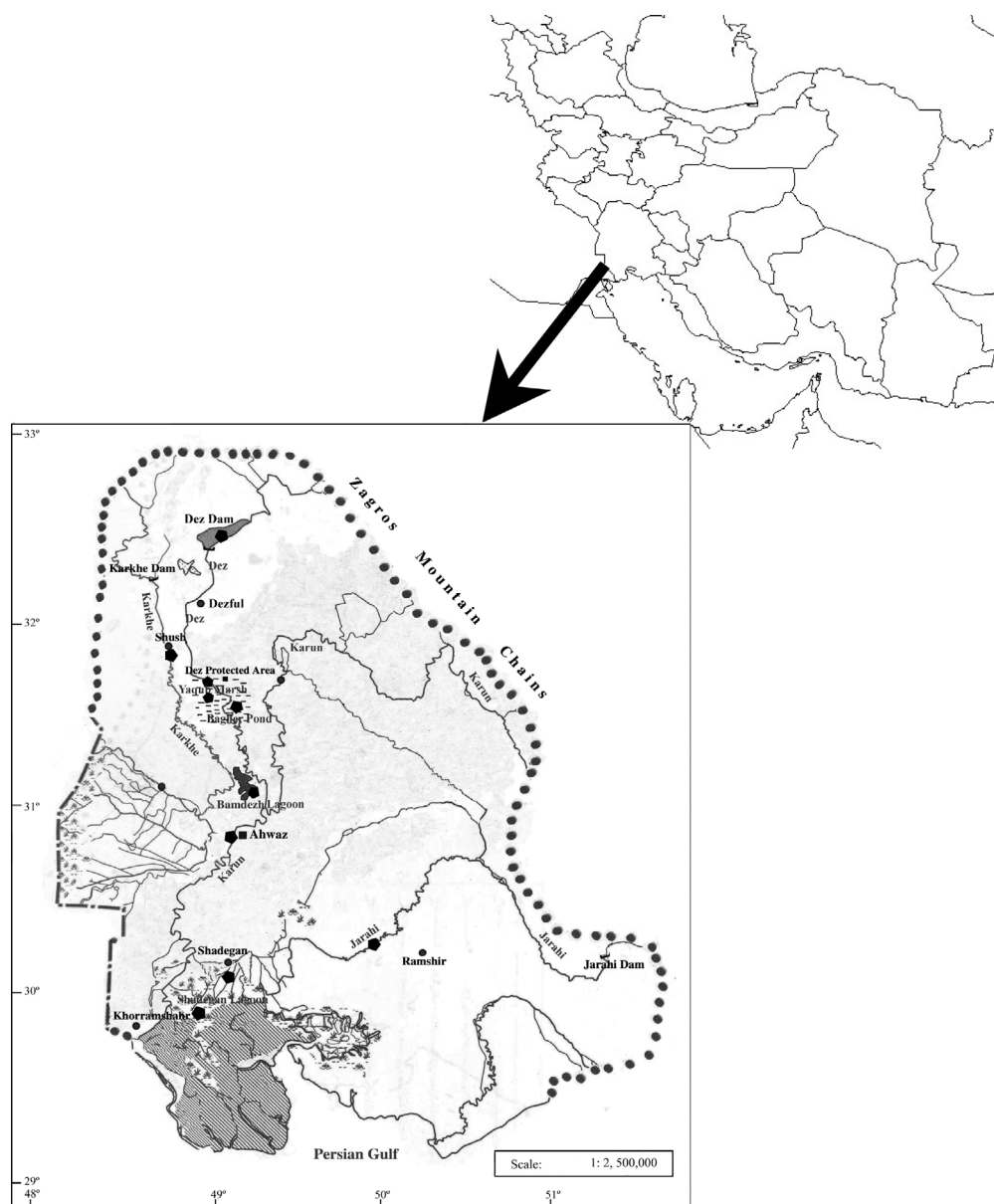


Figure 1. Geographical location of the Khuzestan province, southwest of Iran. Hexagonal marks indicate the sampling sites.

Bamdezh is a freshwater marsh with relatively fewer macrophytes in comparison with the other lotic sampling stations. The surrounding area of this marsh is one of the driest places in Iran (BehroziRad, 2008). Shadegan Lagoon, located in the coastal arid region of Khuzestan, is more saline in the southern part, relative to the more brackish environment of its central parts (BehroziRad, 2008).

3. Results

During the study, we identified 66 species of monogonont rotifers belonging to 21 genera from 12 families (Table 2). Furthermore, 13 species of the family Notommatidae

were collected and identified down to the genus level. Taking those into account, Notommatidae, Lecanidae, and Brachionidae were the most diverse families among the Khuzestan rotifers. From those 13 unidentified species of Notommatidae, 6 species belonged to the genus *Cephalodella*, 5 to *Notommata*, and 2 to *Monommata*. Considering these results, the most specious genera in Khuzestan are *Lecane*, *Cephalodella*, *Brachionus*, and *Notommata* with 17, 9, 7, and 7 species, respectively. In addition to Notommatidae rotifers, 3 *Synchaeta* sp., 2 *Proales* sp., 1 *Lindia* sp., 1 *Scaridium* sp., 1 *Polyarthra* sp., 1 *Hexarthra* sp., and 1 *Trochosphaera* sp. were identified to the genus level, as well.

The most frequently observed species in Khuzestan, in decreasing order, were *Colurella sanoamuangae*, *Keratella tropica*, *Trichotria tetractis similis*, *Cephalodella gibba*, *Macrochaetus collinsii*, *Asplanchna priodonta*, *Keratella cochlearis cochlearis*, *Brachionus calyciflorus*, *Brachionus cf. plicatilis plicatilis*, *Brachionus urceolaris urceolaris*, *Lecane bulla bulla*, and *Lecane luna* (Table 3). While some species, e.g., *Colurella sanoamuangae*, were observed throughout the year, others, e.g., *Notholca salina salina*, were present during one season only (Table 3).

More than one-third of the species (25 species) found in this study are new records for the rotifer fauna of Iran (Table 2), among which *Colurella sanoamuangae* (Figures

2a and 2b) is new to the Palearctic region, and by finding *Lecane inconspicua* (Figure 2c), this species can now be considered as an endemic species of the Palearctic region. The majority (15 species) of those 25 species, however, showed limited temporal and spatial distributions (Table 3).

The presence of brackish water species, e.g., *Brachionus cf. rotundiformis* and *B. cf. plicatilis* (Figures 2d and 2e), in Shadegan Lagoon was notable, although *B. cf. plicatilis* was also found in freshwater sites (Table 3).

Furthermore, we also found 2 specimens of 2 previously undescribed species of the genus *Dicranophorus* (Figures 3a and 3b), which require more specimens before adequate and accurate descriptions, can be made.

Table 3. Seasonal distributions of rotifer species and their presence in different sites (Kan: Karun River; Kar: Karkhe River; Bam: Bamdezh Lagoon; Bgh: Bagher pond; Yaq: Yaqub marsh; Dez: Dez River; Dam: Dez Dam Lake; Jah: Jarahi River; Sha.M: Middle part of Shadegan Lagoon; Sha.S: southern part of Shadegan Lagoon).

Species	Stations	Spring	Summer	Fall	Winter
<i>Asplanchna brightwellii</i>	Kan-Bam	*		*	
<i>Asplanchna priodonta</i>	Kar-Sha.M-Sha.S-Dam-Jah	*		*	*
<i>Aspelta angusta</i>	Dez	*			
<i>Brachionus angularis</i>	Bam-Kan-Yaq		*	*	
<i>Brachionus calyciflorus</i>	Kan-Bam-Sha.M-Sha.S	*	*	*	
<i>Brachionus diversicornis</i>	Dez-Bgh		*	*	
<i>Brachionus cf. plicatilis plicatilis</i>	Kan-Bgh-Sha.M-Sha.S	*	*	*	
<i>Brachionus quadridentatus quadridentatus</i>	Kan	*	*		
<i>Brachionus cf. rotundiformis</i>	Sha.M-Sha.S		*	*	
<i>Brachionus urceolaris urceolaris</i>	Kar-Kan-Bam	*	*	*	*
<i>Cephalodella major</i>	Yaq		*		
<i>Cephalodella forficula</i>	Sha.M-Bgh		*		
<i>Cephalodella gibba</i>	Kar-Sha.M-Dez-Bgh	*	*	*	*
<i>Colurella adriatica</i>	Dez-Sha.S	*			
<i>Colurella sanoamuangae</i>	Bam-Sha.S-Sha.M-Kar-Dez-Jah	*	*	*	*
<i>Colurella uncinata bicuspidata</i>	Sha.M	*			
<i>Dicranophoroides caudatus</i>	Yaq			*	
<i>Encentrum putorius</i>	Kar			*	
<i>Eosphora cf. anthadis</i>	Dez	*			
<i>Euchlanis dilatata dilatata</i>	Kan-Dez-Bgh-Yaq-Dam	*	*		
<i>Euchlanis lyra</i>	Dez	*			
<i>Keratella cochlearis cochlearis</i>	Kar-Sha.S-Jah-Kan-Dam	*	*		*
<i>Keratella tecta</i>	Kar		*		
<i>Keratella quadrata quadrata</i>	Dez				*
<i>Keratella tropica</i>	Kan-Bgh-Yaq-Bam-Kar-Dez	*	*	*	*
<i>Lecane aculeata</i>	Dez		*		

Table 3. (Continued).

Species	Stations	Spring	Summer	Fall	Winter
<i>Lecane bifastigata</i>	Yaq		*		
<i>Lecane bulla bulla</i>	Yaq-Bam-Kar	*	*	*	*
<i>Lecane closterocerca</i>	Kan-Kar-Dez	*			*
<i>Lecane grandis</i>	Sha.M-Bam		*		
<i>Lecane hamata</i>	Yaq-Dez	*	*		
<i>Lecane inconspicua</i>	Sha.M	*			*
<i>Lecane lamellata</i>	Sha.M	*			
<i>Lecane luna</i>	Bam-Bgh-Dam-Dez	*	*	*	
<i>Lecane lunaris</i>	Yaq-Bam-Dez-Dam	*	*		
<i>Lecane papuana</i>	Dez		*		
<i>Lecane plesia</i>	Sh.M		*		
<i>Lecane punctata</i>	Sha.M-Sha.S-Jah	*		*	*
<i>Lecane pyriformis</i>	Dez	*			
<i>Lecane scutata</i>	Dez	*			
<i>Lecane stenroosi</i>	Bgh-Dez-Dam	*	*		*
<i>Lecane thalera</i>	Dez-Bgh		*		
<i>Lepadella quadricarinata</i>	Yaq			*	
<i>Lepadella patella patella</i>	Dez-Yaq	*	*	*	
<i>Lindia torulosa</i>	Dez-Bgh-Yaq		*		
<i>Lophocharis oxysternon</i>	Bgh-Dez-Kar		*	*	
<i>Lophocharis salpina</i>	Jah-Bam		*	*	
<i>Macrochaetus altamirai</i>	Dam-Sha.M	*			
<i>Macrochaetus collinsii</i>	Bgh-Dez-Yaq-Sha.M	*	*	*	*
<i>Mytilina ventralis brevispina</i>	Yaq		*		
<i>Notholca salina salina</i>	Sha.M				*
<i>Notommata copeus</i>	Yaq	*			
<i>Notommata tripus</i>	Yaq		*		
<i>Paradicranophorus aculeatus</i>	Kar				*
<i>Pleurotrocha atlantica</i>	Sha.S		*		
<i>Pleurotrocha petromyzon</i>	Bgh-Bam-Kar		*	*	
<i>Proales theodora</i>	Jah		*		
<i>Resticula melandocus</i>	Kar			*	
<i>Squatinella lamellaris</i>	Yaq			*	
<i>Squatinella rostrum</i>	Yaq			*	
<i>Taphrocampa annulosa</i>	Yaq		*		
<i>Trichocerca porcellus</i>	Sha.M		*		
<i>Trichocerca pusilla</i>	Bgh		*		
<i>Trichotria pocillum</i>	Bam			*	
<i>Trichotria tetractis similis</i>	Dam-Bgh-Yaq-Bam-Dez-Kar	*	*	*	
<i>Tripleuchlanis plicata</i>	Dez-Bgh-Yaq-Bam-Sha.M		*	*	

The Sørensen similarity index showed that the similarities between rotifer fauna of Khuzestan and those of the rest of Iran and the Palearctic, Oriental, and Afrotropical regions were 35%, 9%, 14%, and 17%, respectively (Table 4).

4. Discussion

So far 156 species of rotifers have been reported from Iran. With the addition of the new records obtained during the present study, that number has increased dramatically to 177 species. All in all, 66 rotifer species were recovered

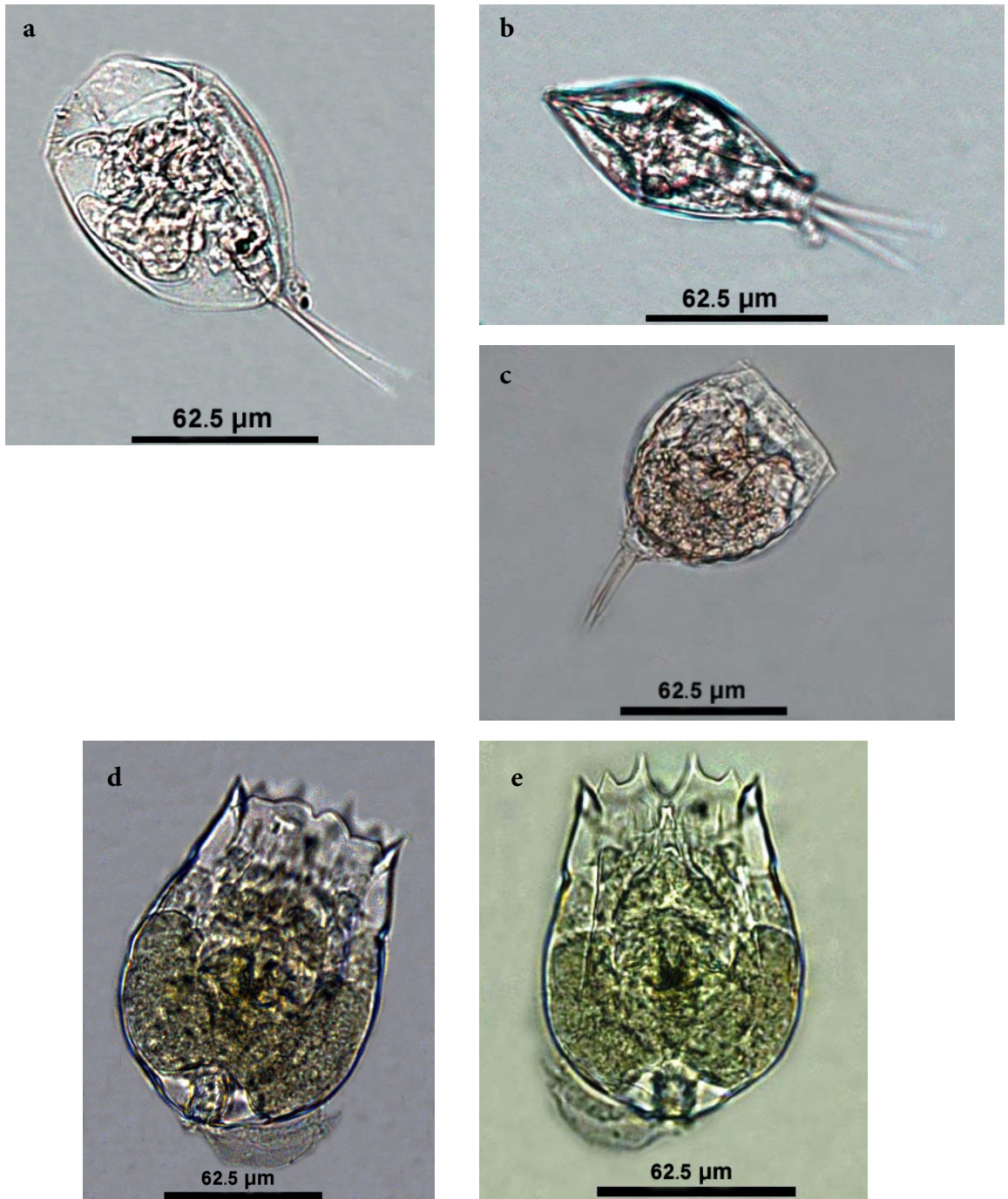


Figure 2. Photomicrographs of some of the rotifer species found in Khuzestan: a) *Colurella sanoamuangae* (lateral view); b) *Colurella sanoamuangae* (ventral view); c) *Lecane inconspicua*; d) *Brachionus* cf. *rotundiformis* (ventral view); e) *Brachionus* cf. *rotundiformis* (dorsal view).

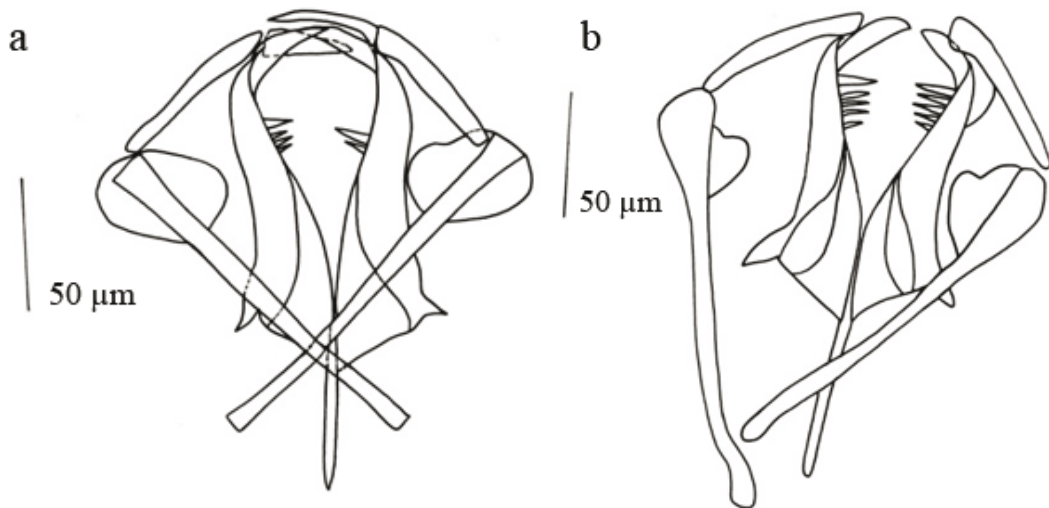


Figure 3. Drawings of *Dicranophorus* sp trophi. a) *Dicranophorus* sp1; b) *Dicranophorus* sp2.

Table 4. Matrix of similarity coefficients between rotifer species of the study area and those for the other neighboring biogeographical regions (PAL: Palearctic, AFR: Afrotropical, ORI: Oriental, IRI: Iranian), calculated using the Sørensen similarity index.

Area	Khuzestan	PAL	AFR	ORI	IRI
Khuzestan	-	9	14	17	35
PAL	9	-	38	33	14
AFR	14	38	-	53	19
ORI	17	33	53	-	23
IRI	35	14	19	23	-

from Khuzestan Province, of which Notommatidae, Lecanidae, and Brachionidae with 23, 17, and 12 species, respectively, were found to be the most diverse families. Among these families, Notommatidae was also the family with the most species in the Palearctic region (Segers, 2008). These families are common and widely distributed; consequently, those figures were to be expected. The results showed that Khuzestan Province, most probably because of its subtropical location, has a tropicopolitan fauna with most species being thermophilic.

In contrast to results from the few studies from central Iran (Hakimzadeh Khoei, 2007; Kordbacheh, 2010), family Notommatidae, with 23 species, is the most diverse family in Khuzestan. Comparing the proportions of different rotifers families to the studies of Hakimzadeh Khoei et al. (2011) and Kordbacheh and Rahimian (2012), it seems that, unlike the rotifer families of the southern part, Brachionidae and Lecanidae are the most common families in central Iran. Additionally, Notommatidae, with 12 species in the study of Hakimzadeh Khoei et al. (2011) and 4 species in the study of Kordbacheh and Rahimian

(2012), was less diverse than the other families, i.e. Lecanidae, Brachionidae, and Lepadellidae. In the present study, 16 Notommatidae species were recorded in Yaquab marsh, a well-vegetated habitat containing relatively well-developed macrophyte vegetation, supporting a higher diversity of rotifers. The presence of macrophyte communities usually creates a wide range of habitats and provides a variety of ecological niches, as well as new food and shelter opportunities. Hence, macrophyte coverage can be considered as the most important single factor in forming a diverse rotifer fauna (Nogrady, 1993; Arora and Mehra, 2003; Malekzadeh Viayeh, 2010).

Considering the geographic proximity, the rotifer fauna of Iran and that of the Arabian Peninsula could be compared. Segers and Dumont (1993) reported 118 species of monogonont rotifers from the Arabian Peninsula, among which the most diverse genera were *Lecane* (38 species), *Brachionus* (13 species), and *Cephalodella* (11 species). Those findings are similar to ours, which can be linked to the geographical vicinity of the 2 areas, where these 3 are the most specious genera.

Furthermore, on the western border of Iran, Turkey, with 341 records of rotifers, is rich in rotifer diversity. Those differences in rotifer diversity between Iran and Turkey might be a consequence of greater efforts on rotifer-related studies in Turkey. The most diverse genera in Turkey are *Lecane* (46 species), *Cephalodella* (22 species), *Trichocerca* (21 species), and *Brachionus* (15 species) (Ustaoglu et al., 2012). On the other hand, the most speciose genera in Khuzestan are *Lecane*, *Cephalodella*, *Brachionus*, and *Notommata*. In both regions, *Lecane*, *Cephalodella*, and *Brachionus* are the genera with the most species. Analysis of the Palearctic rotifer faunas shows that *Cephalodella* is the predominant genus in this area, followed, in most cases, by *Lecane*, *Lepadella*, *Trichocerca*, and *Brachionus* (Segers, 2008).

The littoral species of the genus *Lecane* exhibited a wider variation in their distribution patterns when compared with pelagic rotifers (e.g., *Brachionidae*), also noted by Segers (1996). Similar to the findings of Sharma (1998, as cited in Arora and Mehra, 2003) in India, we found that the “tropic-centered” genera, i.e. *Lecane* and *Brachionus*, were the most diverse groups in Khuzestan. Among the species found in our study, members of the genus *Lecane* (i.e. *L. bulla bulla*, *L. closteroerca*, *L. luna*, and *L. lunaris*) were the most common species, which followed their global proportional patterns (Kuczynska-Kippen, 2005). The presence of brackish-water species *B. cf. plicatilis* and *B. cf. rotundiformis* was remarkable in the southern part of Shadegan Lagoon. Like Rong et al. (1998), we ascribe the high abundance of those 2 euryhaline species (Kotani et al. 2005) to the high salinity of their habitats, which itself was a result of the arid climate of the region and the connection of the lagoon, through its southern part, to the Persian Gulf.

During the winter months, specimens of *Notholca salina*, a species belonging to *Notholca*, which contains both stenothermic and euryhaline species (Koste and Shiel, 1987), were collected from the brackish part of Shadegan Lagoon. The relatively lower water temperature during winter, in comparison with the temperature in other seasons (Table 3), and the higher salinity of the lagoon could explain the presence of *N. salina*. Hence, *N. salina* can be considered as a cold-water species that can even occur in subtropical areas, unlike other members of its genus, which are common in and restricted to the Arctic and temperate northern hemisphere and consequently known as strict cold-water species (Segers, 2003).

Khuzestan lies close to the Tropic of Cancer; hence, its temperature is similar to that of the equatorial zone, being more or less constant throughout the year, although the temperature range is wider here in Khuzestan. Another area with a temperature more or less similar to that of the Tropic of Cancer is Southeast Asia. The main components of the rotifer fauna of Southeast Asia are

thermophilic species (Segers, 2001). Consequently, given the similarities in temperature and the absence of any major biogeographical barrier between Khuzestan and Southeast Asia, at least for rotifers to disperse, and the high intrinsic dispersal ability of rotifers, it could have been expected that the rotifer fauna of Khuzestan would have more or less similar characteristics to those of the Oriental region. Considering the climatic nature of Khuzestan, the predominance of tropic-centered genera *Lecane* and *Brachionus* here may indicate the thermophilic nature of *Lecane* and *Brachionus* representatives in Khuzestan, as previously stated by Segers (2001, 2003) for the Southeast Asian representative of those genera. The presence of both *Colurella sanoamuangae*, hitherto considered a Thai endemic (Segers, 2001), and *Lecane bifastigata*, a rare species of the Palearctic and Oriental regions (Segers, 1995, 1996), in Khuzestan are remarkable. The similarities between the Palearctic and Iranian rotifer faunas are relatively low (Table 4), which can be a consequence of either the limited number of studies on the rotifer fauna of Iran, climatic differences, or both. *Paradicranophorus aculeatus*, an endemic species of the Palearctic, was also found in this study. Taking into account that most elements of the rotifer fauna of Iran known to date, including that of Khuzestan, are tropical and/or subtropical species, it is not surprising that this fauna is a combination of representative elements of those 3 regions and is closest to that of the Afrotropical and Oriental regions, as revealed by the relatively high similarities between their faunas (Table 4). Furthermore, the presence of *Cephalodella maior*, *Lecane sympoda*, and *Notholca acuminata* in this area, which have been recorded from both the Palearctic and Afrotropic, as well as the presence of *Lepadella punctata*, which has been reported from the Palearctic and Oriental (Segers, 2007; Hakimzadeh Khoei et al., 2011), may be a clue to the possible multiorigin nature of Iran's rotifer fauna.

Khuzestan Province has a tropical-subtropical climate and is located on the northern edge of the Arabia-Africa tectonic plate (Khosrotehrani, 2007). Geological studies (Motyei, 1993) have revealed that there is an intracontinental derivation between Central Iran and Zagros-Arabia. This historical factor may explain some taxonomical differences between the rotifer fauna of the Iranian southern and central plains. We identified some species in Khuzestan that had already been reported from adjacent southern areas. Segers and Dumont (1993) identified 118 species of Monogonont rotifers from different countries along the southern coasts of the Persian Gulf, of which 36 species are in common with those found in the present study (those identified to the specific level only). Among those common species, the presence of *Lecane inconspicua* (a rare species of the Palearctic) and *L. bifastigata* (a rare species of the Palearctic and Oriental)

(Segers, 1995) is striking. So far, *Lecane inconspicua* has only been recorded from Arabia (Segers and Dumont, 1993; Segers, 2007). The occurrence of *L. inconspicua* in southern Iran can be explained by the proximity of the type locality and Khuzestan Province.

Dumont (1983) pointed to the exchange of faunas via the Bering Strait as the cause of the presence of common species in Asia, North America, and North Europe, and the same line of reasoning has been proposed for other common terrestrial and freshwater living organisms of those areas (Brown and Lomolino, 1998). Considering the history of faunal exchanges between these 2 regions that have caused faunistic and floristic similarities, these 2 biogeographical regions have sometimes been treated as 1 larger region: the Holarctic (Brown and Lomolino, 1998). We also found 3 species that previously had only been reported from the Palearctic and Nearctic, i.e. *Aspelta angusta*, *Lecane lamellata*, and *Pleurotrocha atlantica*. Consequently, the recording of these 3 species is further evidence of those similarities.

4.1. Comments

Colurella sanoamuangae was reported from Thale Noi Lake in Thailand by Segers and Pholpunthin (1997) as an undescribed *Colurella*. Later, Chittapun et al. (1999) reported it from peat swamps in Phuket Province, Thailand. In 2001 Segers and Chittapun reported *C. sanoamuangae* again, this time as an interstitial rotifer, from the Malay Peninsula. Consequently, Segers (2001) considered *C. sanoamuangae* an endemic species of southern Thailand, although, later on, Sharma and Sharma (2005) found *C. sanoamuangae* in Northeast India, outside of but reasonably close to its type locality. Considering the presence of *C. sanoamuangae* in Khuzestan, it is no longer an endemic species of East Asia, although we may never be certain about how this species found its way to Khuzestan. Padilla and Williams (2004, as cited in Wallace et al., 2006) suggested that the export of ornamental aquatic organisms was a common yet unexplored route for long distance dispersal of many aquatic organisms, particularly for microscopic organisms. Consequently, *C. sanoamuangae* found in Khuzestan might have been translocated with ornamental fish imported from Thailand. The resting eggs or even mature rotifers can easily be distributed in water containing imported fish. This disjunct distribution, on the other hand, may represent a biogeographic relict, a possible, yet highly unlikely, possibility.

Brachionus cf. *rotundiformis* was originally recorded as a variety of *B. muelleri* (= *plicatilis*, O.F.Müller, 1786), based on a description of specimens from the Caspian Sea (Tschugunoff, 1921, as cited in Haberman and Sudzuki, 1998). Later, certain investigations (e.g., Segers, 1995; Sudzuki, 1995, 1996) recognized its status and named it *B. plicatilis rotundiformis* or *B. rotundiformis*. In the present study, specimens of *B. cf. rotundiformis* were collected

from the middle and southern parts of the Shadegan Lagoon, where the salinity was positively influenced by the sea water entering the lagoon from the Persian Gulf. Haberman and Sudzuki (1998) studied *B. cf. rotundiformis* in Lake Palaeostomi (Bulgaria) and found a higher abundance of this species in a part of the lake where the salinity was higher. They concluded that the salinity had a direct relationship with dispersal and abundance of *B. cf. rotundiformis*, which seems to be the case here, too.

Lecane inconspicua was reported by Segers and Dumont (1993), who considered it an endemic taxon of Saudi Arabia. Hitherto, the species had only been recorded from several localities in the east of Saudi Arabia (Segers, 1995, 2007). With our record, *L. inconspicua* is reported as an endemic species of the southwest part of the Palearctic region.

The specimens of *L. inconspicua* were only collected from the middle region of Shadegan Lagoon in spring and winter. This finding confirms the euryhaline nature of *L. inconspicua* as previously proposed by Segers and Dumont (1993). We found this species in Shadegan Lagoon, a brackish environment, suggesting its adaptations to saline waters, although it has been reported from freshwater habitats (Segers and Dumont, 1993).

4.2. Conclusions

As a result of this work, 25 new species have been added to Iran's rotifer list. A large proportion of those species belong to the genus *Lecane*. Considering the biogeography of different species found here, it is apparent that most of them are widely distributed tropicopolitan species, except *C. sanoamuangae*, *L. inconspicua*, and *L. bifastigata*, which are rare species, even in their endemic areas, the Oriental, Palearctic, and Palearctic-Oriental regions, respectively.

Khuzestan Province is isolated from the rest of the country by the Zagros Mountain chain. Based on our zoogeographical analysis, Khuzestan's rotifer fauna is distinct from those of other parts of Iran and more similar to that of the Arabian-African and, to some extent, the rotifer fauna of Oriental Southeast Asia. The study of Iranian rotifers is still in its initial stages and much remains to be done to have a reliable checklist of the rotifer species from this part of the world.

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