Oligochaetes (Annelida, Clitellata) in the Anzali International Wetland, north-western Iran

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Abstract. In order to determine the Oligochaeta fauna of the Anzali International Wetland (north-western Iran), samples of bottom sediment and aquatic vegetation were collected from 13 stations eight times from August 2012 to June 2013. As a result of the study, 11 species and one genus were identified: *Tubifex tubifex*, *Limnodrilus claparedeianus*, *L. hoffmeisteri*, *Potamothrix hammoniensis*, *P. bedoti*, *Branchiura sowerbyi*, *Nais pardalis*, *Ophidonais serpentina*, *Dero digitata*, *Stylaria lacustris*, *Slavina appendiculata*, and *Mesenchytraeus* sp. Some physico-chemical parameters of the water (depth, temperature, dissolved oxygen, and pH) were measured at the sampling site. The average density of the total oligochaete community in the benthos of the wetland was 6077 ind. m^{-2}. The Shannon–Wiener diversity index was on average 0.92, with a maximum of 1.57 and a minimum of 0.44 at different stations. Results indicated that the maximum and the minimum density were observed in June (21 837 ind. m^{-2}) and in December (1041.9 ind. m^{-2}), respectively. Most frequent and abundant species were the tubificids *L. hoffmeisteri*, *L. claparedeianus*, and *P. hammoniensis*. All determined oligochaete taxa except *T. tubifex* were new to the Anzali Wetland, including seven new to the fauna of Iran. The structure of the Oligochaeta community correlated with the progression of the trophic state of the aquatic ecosystem.

Key words: Oligochaeta, fauna, Anzali Wetland, Iran.

INTRODUCTION

Transitional waters, for example lagoons, represent important but fragile ecosystems in the coastal landscape, providing key ecosystem services such as water quality improvement, fisheries resources, habitat and food for migratory and resident animals, and recreational areas for human populations. The Anzali International

Wetland was registered in the Ramsar Convention in 1975 as Ramsar Site #40, Wetlands International Site Reference No. 2IR005 (JICA 2005). The Anzali Wetland complex comprises large, shallow, eutrophic freshwater lagoons, shallow impoundments, marshes, and seasonally flooded grasslands at the south-western coast of the Caspian Sea (Fig. 1). It consists of different aquatic and dry land ecosystems and is a good example of a natural habitat supporting an extremely diverse wetland flora and fauna (Ayati 2003).

Oligochaete annelids have a worldwide distribution, being frequently the most abundant benthic organisms in freshwater ecosystems; many species are cosmopolitan (Brinkhurst and Jamieson 1971). They are used in biodiversity studies, pollution surveys, and environmental assessment and have also economic importance (Mason 1996; Wetzel et al. 2000; Rodriguez and Reynoldson 2011). Although many researchers have studied the Anzali Wetland from the pollution-related, faunistic, and ecological points of view (e.g. Ayati 2003; JICA 2005; Charkhabi and Sakizadeh 2006; Akbarzadeh et al. 2008; Jafari 2009; Taher-shamsi et al. 2009; Mirzajani et al. 2010; Pourang et al. 2010; Jamshidi-Zanjani and Saeedi 2013), there are no data on the species diversity of the Oligochaeta of the region, except the single record of *Tubifex tubifex* by Pourang (1996). The aquatic Oligochaeta species of Iran are mentioned only in a few papers: Stephenson (1920), Egglishaw (1980), Aliyev and Ahmadi (2010), Ahmadi et al. (2011, 2012), Ardalan et al. (2011), Jabłońska and Pesić (2014). Until now 19 species of aquatic oligochaetes occurring in inland waters of Iran have been recorded. The aim of this study was to evaluate the diversity and distribution of this group and to contribute to the Oligochaeta fauna of both the Anzali Wetland and Iran.

MATERIAL AND METHODS

Study area

The Anzali International Wetland (37°28′ N, 49°25′ W), one of the largest freshwater coastal wetlands of Iran, is located in the Guilan Province at the south-western coast of the Caspian Sea and covers an area of 193 km^2 (Pourang et al. 2010) (Fig. 1). The main wetland covers about 11 000 ha; it comprises an open freshwater lagoon with a length of 26 km and a width of 2.0–3.5 km, surrounded by reed beds extending its eastern border for another 7 km. Eleven rivers and groundwater seeps feed the wetland. The wetland complex is separated from the Caspian Sea by a dune system; the passage to the sea has a width of 426 m. The wetland supports extensive reed beds and an abundant submerged and floating macrovegetation. Its permanently aquatic portion is surrounded by seasonally flooded marshes and water impoundments, which are also fringed by reed beds and damp grassland. The southern part of the wetland is mainly adjacent to rice fields and patches of woodland, while the northern part borders on sand dunes with

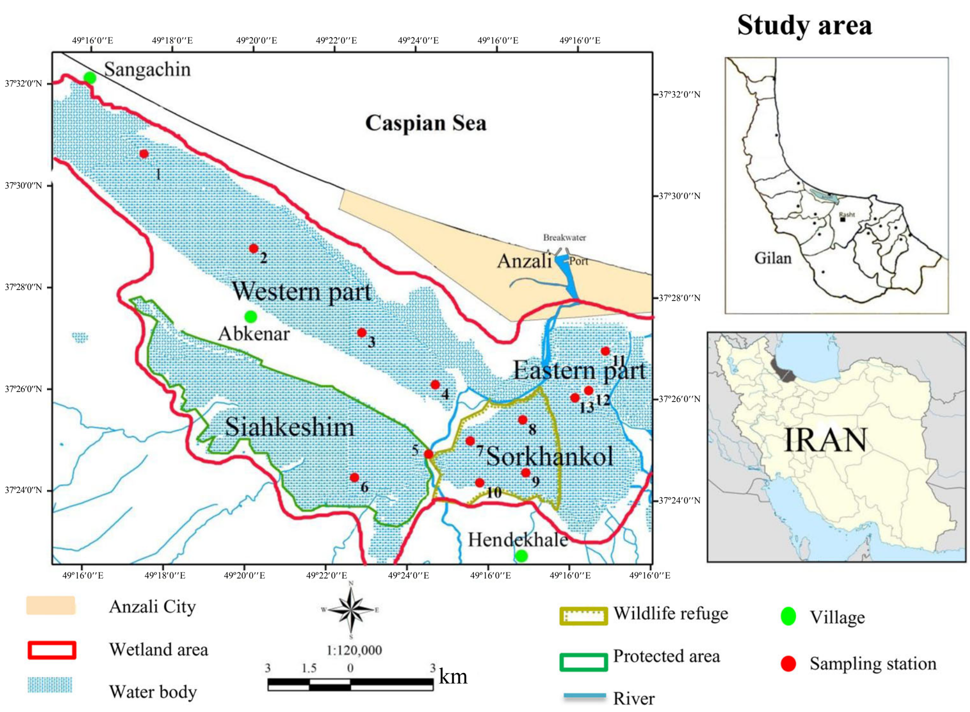

Fig. 1. Study area and sampling stations.

grassland and a scrubby vegetation. The wetland consists of four main parts: the western, the central (Sorkhankol Wildlife Refuge), the south-western (Siahkeshim Protected Area), and the eastern; the last part has different physico-chemical, morphologic, phytoecological, and geographical characteristics, including a higher anthropogenic pressure (Ayati 2003).

Total precipitation in the Anzali Wetland is about 1500 to 2000 mm y^{-1}. Maximum water depth is about 3 m but it is fluctuating (Jafari 2009). The water depth has decreased, owing to solid sedimentation, in some parts to less than 0.5 m (Ayati 2003). In the last ten years, salinity has slightly increased with the rise of the level of the Caspian Sea, which has caused more intensive mixing of water, as well as with the inflow of salt from increased upstream irrigation. Nevertheless, the Anzali Wetland is still considered a freshwater wetland with salinity values of less than 0.5 ppt (JICA 2005).

Among the 24 identified macrophyte species, *Phragmites australis* is dominating. The Anzali Wetland is occupied by eutrafent plant species. *Myriophyllum* has been replaced by *Ceratophyllum*, Lemnaceae, and *Typha*, which prefer a eutrophic condition. *Potamogeton* spp. are also increasing and dominant in open water such as stretches in the western part. The Anzali Wetland complex is extremely important for a wide variety of breeding and migrating waterbirds, and supports huge numbers of wintering ducks, geese, swans, and coots (Scott 1995). Due to the geology of the catchment, the western and north-western parts of the study area are characterized by higher carbonate content and finer sediments than the eastern and south-eastern parts where the bottom consists mostly of gravel, sand, and silt (Jamshidi-Zanjani and Saeedi 2013).

In the recent years, eutrophication has become a serious problem due to increased wastewater loading to the International Anzali Wetland ecosystem from industrial, agricultural, and domestic sources (Akbarzadeh et al. 2008; Mirzajani et al. 2010).

Sampling and sample processing

Aquatic oligochaetes were collected twice a season from 13 sites in the Anzali Wetland from August 2012 to June 2013. Stations 1–4 are located in the western part, stations 5 and 6 are in the south-western part (Siahkeshim Protected Area), stations 7–10 in the central part (Sorkhankol Wildlife Refuge), and stations 11–13 in the eastern part of the wetland (Fig. 1).

The samples were taken with a bottom grab (0.04 m^2) from the surface layer of bottom sediments among the submerged macrovegetation. In the field, the samples were washed on a 500 μm mesh size sieve and preserved with a 10% formalin solution. In laboratory, animals were picked from the sieve residue and transferred to 70% ethanol. Specimens were mounted in Amman's lactophenol or glycerine on microscope slides covered with a cover slip and left for transparency in this fluid for several hours before examination.

Identification followed Kathman and Brinkhurst (1998) and Timm (1999). The voucher specimens were mounted in Canada balsam and deposited by the second author in the Oligochaeta collection at the Centre for Limnology of the Estonian University of Life Sciences, Rannu, under codes S-4325 to S-4340.

Physico-chemical factors

Given that the Anzali Wetland is shallow, water samples were taken from the bottom. During each sampling period, water temperature was measured with a thermometer with a sensitivity of 0.1 °C, dissolved oxygen was measured with an oxygen meter WTW-OXI 330/SET, and pH was determined with a pH meter WTW pH 330/SET-1.

Data analysis

All statistical procedures (charting and average and standard deviation calculation) were performed using Excel 2010. The values of species diversity (H') were calculated according to the Shannon–Wiener species diversity index.

RESULTS

The monthly variations and average values of some physico-chemical measurements are presented in Figs 2 and 3. The average water temperature at all stations was 18.3±0.4°C for the whole sampling period, the level of dissolved oxygen

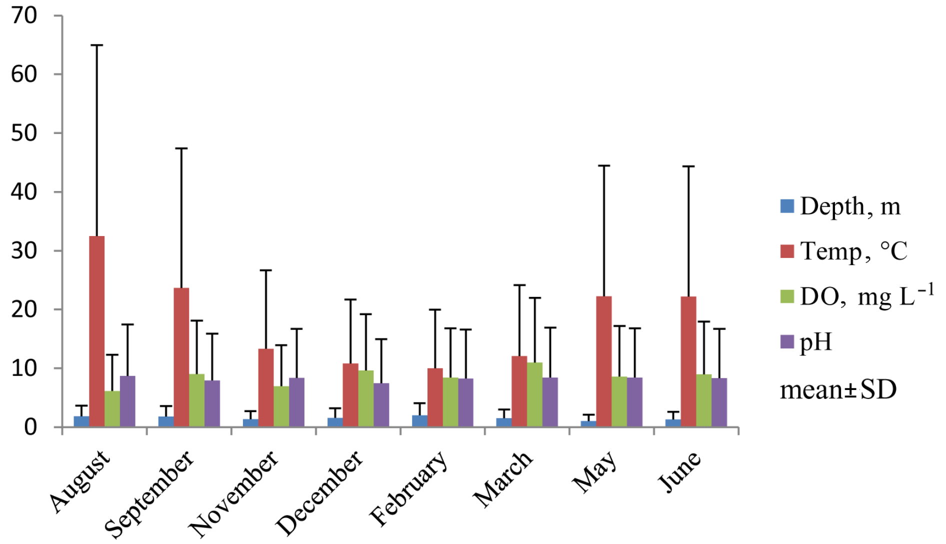

Fig. 2. Seasonal average values of physico-chemical parameters. DO – dissolved oxygen; Temp – temperature.

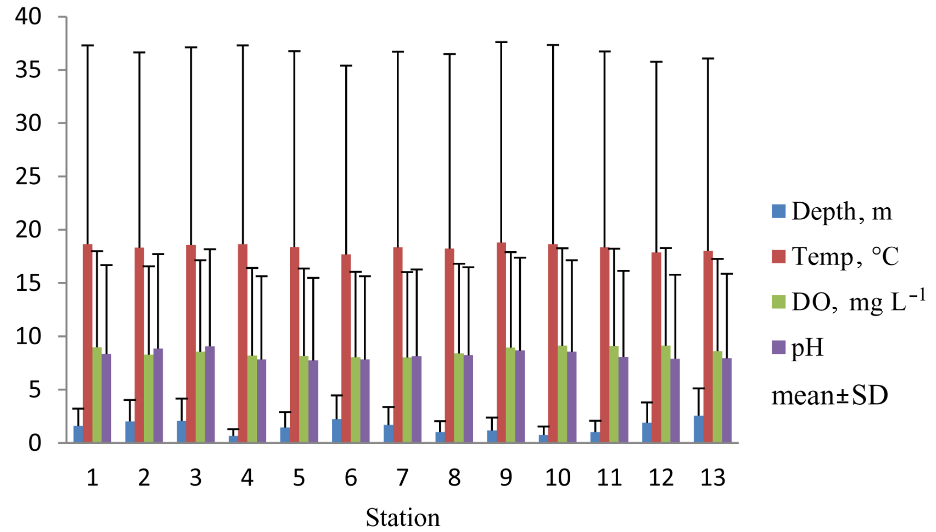

Fig. 3. Average values of physico-chemical parameters at the investigated stations. DO – dissolved oxygen; Temp – temperature.

was 8.55±0.4 mg L^{-1}, and the average pH was 8.17±0.4. The average water depth was 1.55±0.6 m.

The maximum temperature was observed in August (32.5 °C) and the minimum in February (9.9 °C). The maximum average of depth was in February (2.03 m) and the minimum in May (1.05 m). The lowest level of dissolved oxygen mean was recorded (6.14 mg L^{-1}) in August, and the highest level was in March (11 mg L^{-1}). Also the maximum mean of pH was measured in August (8.73) while the minimum was measured in December (7.48). Spatially, station 13 had the maximum depth (2.56 m) and station 4 the minimum depth (0.66 m). The lowest level of dissolved oxygen (8.02 mg L^{-1}) was recorded at station 7 and the highest level (9.15 mg L^{-1}) at station 12. The minimum level of pH (7.75) was measured at station 5 and the maximum of it (9.09) at station 3.

Oligochaete fauna

During the survey, 11 species and one genus of Oligochaeta were found. Of these six species belong to the Tubificidae: *Tubifex tubifex* (Müller, 1774), *Limnodrilus hoffmeisteri* (Claparède, 1862), *Limnodrilus claparedeianus* (Ratzel, 1868), *Potamothrix hammoniensis* (Michaelsen, 1901), *Potamothrix bedoti* (Piguet, 1913), and *Branchiura sowerbyi* (Beddard, 1892); five species to the Naididae: *Nais pardalis* (Piguet, 1906), *Ophidonais serpentina* (Müller, 1774), *Dero digitata* (Müller, 1773), *Slavina appendiculata* (d'Udekem, 1855), and *Stylaria lacustris* (Linnaeus, 1767); and the genus *Mesenchytraeus* to Enchytraeidae. All determined oligochaete taxa except *T. tubifex* were new to the Anzali International Wetland. Seven taxa including *L. claparedeianus*, *P. hammoniensis*, *P. bedoti*, *N. pardalis*, *D. digitata*, *S. appendiculata*, and *Mesenchytraeus* sp. were new to the fauna of Iran. This paper updated the very short checklist of Iranian aquatic oligochaetes (14 species after Jabłońska and Pesić 2014, and one more species in Basim et al. 2012) to 23 species.

The abundance of each species is presented in Table 1. The total average density of oligochaetes in the benthos of the wetland was 6077 ind. m^{-2}. During the study, the most frequent and abundant species were the tubificids *Limnodrilus hoffmeisteri*, *L. claparedeianus*, *Potamothrix hammoniensis* (recorded at all 13 stations), *Tubifex tubifex*, and the naidid *Dero digitata* (at 12 stations) (Fig. 2). The dominant species, *L. hoffmeisteri*, was on average represented with 2473 ind. m^{-2}, followed by *L. claparedeianus* with 2291 ind. m^{-2}. The former was the most abundant in summer, the latter in spring; both species were the most abundant at station 8. These two species accounted for 40% and 37% of the total oligochaete community, respectively, in the wetland; the other species were less abundant (Fig. 4). The dominant species showed similar dominance patterns during the study period except May and June (Fig. 5). As is evident from Table 1, station 12

Table 1. Abundance of oligochaetes at the sampling stations of the Anzali Wetland (ind. m^{-2})

Taxon	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	Mean
L. hoffmeisteri	92	260	350	895	4 079	3 528	1 989	7 388	2 249	2 357	1 476	3 546	3 934	2 473
L. claparedeianus	202	280	411	233	4 142	2 703	2 320	6 850	2 205	3 029	2 723	2 903	1 783	2 291
P. hammoniensis	871	383	115	1 182	192	606	759	940	735	1 059	122	30	116	547
P. bedoti	0	0	0	0	0	0	0	0	25	0	119	0	0	11
T. tubifex	0	305	69	425	75	250	350	300	8	425	91	119	75	192
B. sowerbyi	0	0	0	8	126	28	0	25	95	0	237	612	227	104
D. digitata	159	373	149	31	16	0	183	83	1 597	62	1 672	514	936	444
O. serpentina	0	0	0	0	0	65	0	0	0	0	0	0	0	5
S. lacustris	0	0	0	0	0	8	0	0	0	0	0	25	0	3
S. appendiculata	0	0	0	16	8	0	0	0	0	0	0	0	0	2
N. pardalis	0	41	33	0	0	0	0	0	0	0	0	0	0	6
Mesenchytraeus	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.02
Total	1 324	1 642	1 127	2 790	8 638	7 188	5 601	15 586	6 914	6 932	6 440	7 749	7 071	6 077

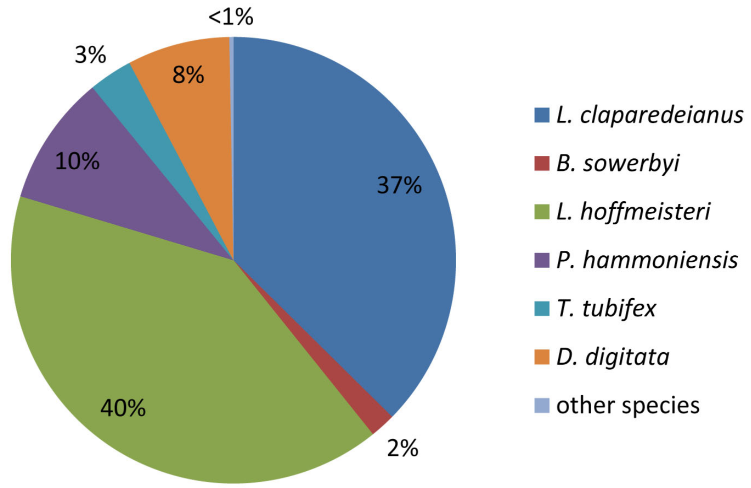

Fig. 4. Relative abundance of Oligochaeta species (%) in the Anzali Wetland.

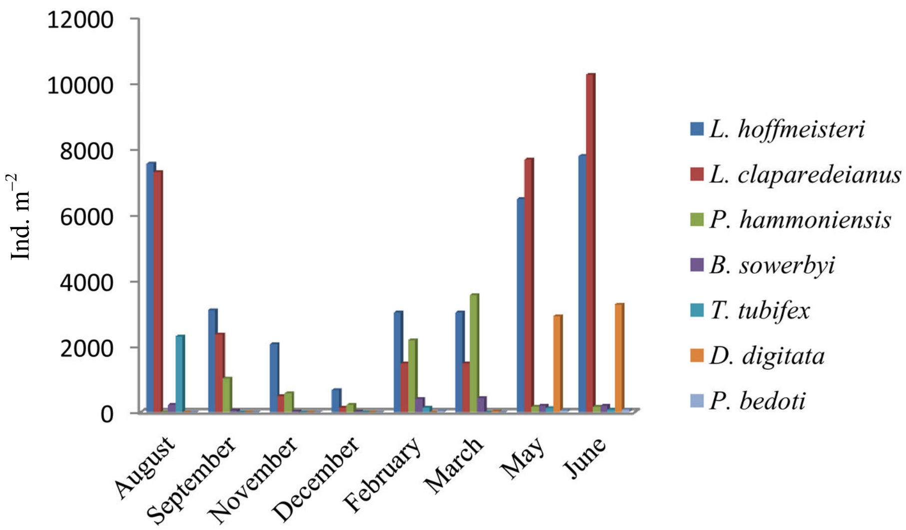

Fig. 5. Seasonal abundances of Oligochaeta species in the Anzali Wetland.

excelled the other stations in terms of species diversity. Contrary to the high level of species diversity of this station, the highest value of the Shannon–Wiener index, varying between 0.12 and 6.12 with a mean of 1.55, was determined for station 11 (6.12) (Fig. 6).

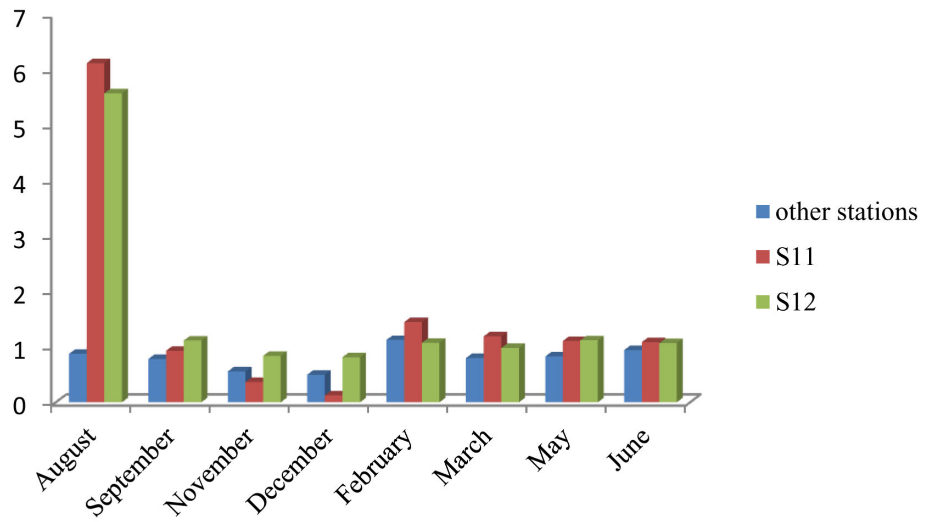

Fig. 6. Seasonal changes of the Shannon–Wiener diversity index values for Oligochaeta in the Anzali Wetland.

DISCUSSION

During the study in the Anzali International Wetland from August 2012 to June 2013, 11 species and one genus of Oligochaeta were found. These are mainly taxa with wide ecological tolerances and with an extensive geographical range. The sediment-dwelling family of Tubificidae, originating from the northern temperate zone (Timm 1980), was represented by four genera. This family and several of its genera (e.g. *Tubifex*, *Limnodrilus*, and *Branchiura*) are considered to be cosmopolitan while the genus *Potamothrix* is Holarctic (Wetzel et al. 2000). Among them, *Limnodrilus hoffmeisteri* is actually a cosmopolitan species, able to reproduce in a sexual manner both in the moderate and in the tropical climate. This species occurs in a wide variety of surface water habitats, being perhaps the most omnipresent and commonly collected freshwater tubificid worldwide (Naveed 2012). It can reach very high abundances in organically enriched areas (Brinkhurst 1971; Uzunov et al. 1988). A classification of some aquatic oligochaetes from the St. Lawrence Great Lakes according to trophic level of integrating water bodies shows that *L. hoffmeisteri* and *L. claparedeianus* are associated with eutrophic level (Howmiller and Beeton 1970). A similar classification for the Scandinavian lakes on the basis of the degree of enrichment indicates that both of them belong to the species tolerating extreme enrichment with organic pollution (Milbrink 1973, 1980). In Iran *L. hoffmeisteri* was found in the Aras River by Aliyev and Ahmadi (2010) and in the Urmia Lake wetlands by Ahmadi et al. (2011). Ahmadi et al. (2012) reported the species from bottom deposits of Noruzloo and Bukan reservoirs in Iran. Although it is lacking in tropical countries, *L. claparedeianus*, a newly presented species in this study, prefers a somewhat warmer climate. It is scarce in northern Europe including Estonia and Sweden (Timm 1970; Erséus et al. 2005) but is as abundant like *L. hoffmeisteri* in the Tsimlyansk Reservoir on the Don River (southern Russia) (Dolidze 1994), as well as in the Anzali Wetland. The absence of *Limnodrilus udekemianus* Claparède, 1962, another species common in many European polluted waters (Brinkhurst and Jamieson 1971) and known also from the reservoirs on the Zarrineh River in Iran (Ahmadi et al. 2012), is puzzling in the Anzali Wetland.

Potamothrix hammoniensis has a wide distribution pattern in fresh water and can be rarely found also in brackish water. It tolerates considerable organic pollution and other factors of eutrophication (Milbrink 1973, 1980; Lang 1978; Rodriguez and Reynoldson, 2011). It is a common and often dominating tubificid species in the profundal of many European eutrophic lakes (Timm 2013). Ojaveer et al. (2002) noted that the species has spread from the Caspian and Ponto-Azovian regions to Europe and other continents. The small, architomically reproducing *P. bedoti* is another, entirely freshwater species, of this genus in the Anzali Wetland. The numerous other congeners common in the estuaries of the Ponto-Caspian system (Finogenova 1980) or in the lakes connected with the Baltic Sea (Milbrink 1970; Timm 2013) and tolerating weak salinity, such as *P. moldaviensis* (Vejdovský et Mrázek, 1903), *P. bavaricus* (Oschmann, 1913), or *P. heuscheri* (Bretscher, 1900), are lacking in the material collected in the Anzali Wetland. Before this study, there was no report of *P. hammoniensis* and *P. bedoti* in Iran.

Tubifex tubifex was first reported from Iran by Egglishaw (1980), from the Bereghan River near Tehran. Pourang (1996) found the species in the Anzali Wetland. Ahmadi et al. (2012) collected *T. tubifex* in the Zarrineh River in the West Azarbaijan Province. The species can thrive both in organically polluted and oligotrophic habitats (Timm 1970; Milbrink 1973, 1980). It is most widely known as a species characteristic of strongly polluted waters (Lang 1978; Poddubnaya 1980). However, *T. tubifex* occurs most abundantly both in eutrophic and oligotrophic environments when competition and predation are weak (Milbrink 1973; Dumnicka and Galas 2002). Owing to its ability of rapid sexual and parthenogenetic reproduction (Poddubnaya 1984), it is often a pioneer species in freshly created or temporary ponds, water reservoirs, canals, etc. (Anlauf 1989). Its subordinate position in the Anzali Wetland can indicate that the ecosystem there was established long ago. Timm (1996) considers that *T. tubifex* characterizes unstable environments while *P. hammoniensis* the more stable ones. Timm et al. (1994) believe that the response of the benthic Oligochaeta community to the lake enrichment with nutrients consists in mass development firstly of ubiquitous *L. hoffmeisteri* and, later on, of the 'eutrophic' *P. hammoniensis*. In the progressively eutrophying Danube Delta lakes, Rîşnoveanu and Vădineanu (2001) observed rising dominance of *P. hammoniensis* and *L. hoffmeisteri* while *T. tubifex* had disappeared from the benthos.

Branchiura sowerbyi has a worldwide distribution in tropical and subtropical fresh waters (Brinkhurst and Jamieson 1971) and is considered to be widespread in North America (Kathman and Brinkhurst 1998). In Iran the species has been collected in the Aras River by Aliyev and Ahmadi (2010) and in the Urmia Lake wetlands by Ahmadi et al. (2011). Ahmadi et al. (2012) reported the species in two reservoirs: Noruzloo and Bukan in the north-west of Iran. It may be an invasive species originating from East Asia. In the cooler climate of northern Europe, *B. sowerbyi* is mostly limited to thermal waters (Aston 1973; Milbrink 1973). However, in East Asia its natural distribution range reaches even the Amur River basin further north (Chekanovskaya 1981). The species is typical in waters with current velocity less than 0.5 m s^{-1} (Paunović et al. 2005). According to Prater et al. (1980), this species is abundant in Ohio (USA) waters with moderate amounts of organic input. It is dominant in some organically enriched rivers and reservoirs in southern Brazil (Pamplin et al. 2005). A high number of Oligochaeta including *B. sowerbyi* were found by Gonçalves et al. (2008) and INOVA (2006) on the Azore Islands in locations influenced by organic enrichment.

The phytophilous family of Naididae was only represented by five species in this study: *Nais pardalis*, *Ophidonais serpentina*, *Dero digitata*, *Slavina appendiculata*, and *Stylaria lacustris*. The most abundant of them was *D. digitata*, a species thriving both on muddy bottoms and aquatic plants. Howmiller and Beeton (1970) reported domination of *D. digitata* at the most eutrophic stations, together with *Limnodrilus* spp. However, Rodriguez and Reynoldson (2011) treated *D. digitata* as a species of mesotrophic or only slightly enriched areas. In a review on the value of oligochaete species as indicators of pollution, Lafont (1984) added the species to the list of tolerant species. Other naidid species were met occasionally in the Anzali Wetland. In all probability, the diversity and abundance of these relatively small worms were underestimated by our sampling methods and deserve further study. *Dero digitata* is new to the Iranian fauna. In Iran of this genus only *D. dorsalis* Ferronierè, 1899 has been found earlier. Jabłońska and Pesić (2014) just reported this species in a pond located in the city of Nowshahr, Mazandaran Province.

The finding of the only representative of the mainly terrestrial family Enchytraeidae, *Mesenchytraeus* sp., may be occasional.

The high density of *L. hoffmeisteri* and *L. claparedeianus*, noted by us at all sampling sites and in all seasons in the Anzali Wetland, is consistent with the results of several relevant research projects carried out there on environmental conditions (Ayati 2003; JICA 2005; Akbarzadeh et al. 2008; Tahershamsi et al. 2009; Mirzajani et al. 2010). According to these studies, the aquatic environment of the wetland is deteriorating as a result of continuous wastewater inflow. Eutrophication has become a serious challenge to the ecosystem of the Anzali International Wetland. The co-domination of *L. hoffmeisteri* and *L. claparedeianus*, as well as the moderate presence of the thermophilous species *Branchiura sowerbyi*, render the oligochaete community of this wetland similar to those of southern Europe. The local Oligochaeta fauna is exclusively a freshwater fauna, without any connection with the fauna of the brackish-water Caspian Sea.

Maximum abundances of the Oligochaeta were observed in May, June, and August. Temperature, depth, and pH were relatively high in summer, reaching their highest level in August while the dissolved oxygen was at its lowest level in this month. The inlets had revealed their maximum discharge in spring (April–May) and the minimum discharge in August while the amount of pollution has increased during the summer (Hosseinzadeh et al. 2013). These conditions may support the maximum abundance of oligochaetes in spring and summer. Already Poddubnaya (1980) stated that changes in the temperature regime, in the level of productivity of the mud, and in the population density result in changes in the time, duration, and intensity of reproduction of the worms causing transformations in the structure and productivity of the populations.

Stations 11 and 12, which are located in the eastern part of the wetland, host a similarly abundant and diverse fauna of Oligochaeta. These two stations are under similar ecological pressure. Most of the industries in the region are operating in the eastern and south-eastern parts of the Anzali catchment area, largely in the city of Rasht (Ayati 2003; JICA 2005). The pollution load from the eastern part of the catchment area is higher compared with that from the other parts of the catchment. Both domestic development and industrial activities have led to the destruction of local aquatic ecosystems (Charkhabi and Sakizadeh 2006). At present, almost all sheltered open-water areas in the south-eastern and eastern basins are covered with a dense floating mat of *Azolla*, which has penetrated also deep into the *Phragmites* stands. Every year large quantities of wastewater and industrial waste enter the eastern parts of the Anzali Wetland from the cities of Rasht and Khomam, supporting the growth of macrophytes and microorganisms. Decomposition of plants consumes oxygen from water, and oxygen deficiency causes the death of sensitive aquatic animals (Jafari 2009). Since most pollution of the area is organic, the tubificid species most tolerant to this kind of pollution (*L. hoffmeisteri* and *L. claparedeianus*) thrive in this region.

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