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Ecological factors affecting aquatic beetle species (Insecta: Coleoptera)

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Aquatic Coleoptera plays a major role in freshwater ecosystems and is regarded as an effective bioindicator. While being widely distributed in Iran, there are few studies that use aquatic Coleoptera to determine environmental quality and conditions. With ample water resources, the province of Chaharmahal & Bakhtiari, Iran, offers an excellent opportunity to explore the effect of environmental characteristics on aquatic beetles. The purpose of this research was to investigate the structure of the community and to determine the dominant factors regulating aquatic beetles in Borujen and Lordegan (as two major provincial towns). Sampling was conducted seasonally for one year (between September 2017 and July 2018) at six stations using standard sampling tools (small net and soft paintbrush), ecological factors such as water temperature, water pH, water electrical conductivity and air temperature were also calculated at each station using appropriate tools. A total of 12 species have been described that belong to 11 genera and 4 families. The largest number of described species was contained in the Dytiscidae family and the smallest number in the Hydrophilidae family. Two species of *Agabus* were the most common insects, namely *Agabus conspersus* and *Agabus bipustulatus*. The study of linear regression found that water temperature with a correlation coefficient of 1,685 was the most powerful factor in the distribution of aquatic Coleoptera and the least important factor was the air temperature with a correlation coefficient of 0,39. Furthermore, canonical correspondence analysis (CCA) revealed that water pH, water electrical conductivity (EC), water temperature (WT) and air temperature (AT) had an impact on aquatic beetle distribution. Our results suggest that water quality plays a key role in aquatic beetle species abundance and can, therefore, be viewed as a freshwater ecosystem health indicator organism.

Key words: *Aquatic Coleoptera, Chaharmahal & Bakhtiari, Dytiscidae, Ecological Factors, Water temperature.*

INTRODUCTION

Aquatic Coleoptera known as water beetles, with more than 13,000 described species, is one of the most abundant aquatic insects (Short, 2018). They play an important role in freshwater ecosystems and are considered as a suitable bioindicator (Dong *et al.*, 2014). Since the preservation of biological diversity (or biodiversity) – as a measure of the variety of all organisms – is one of the main conservation goals for the sustainable use of resources and animal survival, the identification, and evaluation of animal habitats are considered topics of research priority. In this regard, aquatic Coleoptera as biodiversity indicators in freshwater ecosystems are of great importance (Sanchez *et al.,* 2006). Aquatic beetles are widely distributed in the Fars, Guilan, Mazandaran and Khuzestan

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provinces of Iran (Hosseinie, 1992a, 1992b, 1994, 1995a, 1995b), Ardabil (Ostovan & Niakan, 2004), and Markazi (Vafaei *et al.* 2007). Work on the biodiversity of Myxophaga and Adephaga in Iran showed that in Mazandaran, Guilan, Fars and Khuzestan, respectively, the highest species richness was found (Van Vondel *et al.* 2017). Seven species of Haliplidae and 87 species of Dytiscidae are referred to Iranian fauna in the most recent list of Palaearctic beetles-Catalog of Palaearctic Coleoptera- (Nilsson, 2003; Van Vondel, 2003). Further works (Vafaei *et al.*, 2009; Atamehr & Alaei, 2010; Darilmaz *et al.*, 2013; Mousavi *et al.*, 2016, etc.) added an additional 14 species including 6 Haliplidae and 8 Dytiscidae to this amount.

In addition, water hydrographic parameters such as pH, temperature (WT), phosphorus quantity, electrical conductivity (EC) and vegetation are important factors in the population structure of aquatic Coleoptera (Dong *et al.*, 2014; Segura *et al.*, 2007), and pH is the most effective control factor (Dong *et al.,* 2014). Water acidity and alkalinity affect factors essential to the completion of the life cycle, such as food, shelter and egg deposition substrates (Verberk *et al.*, 2001). In addition, hydroperiods are other influencing variables in aquatic Coleoptera dispersion. The investigation has shown that in permanent waters they are more numerous than in temporal waters (Gomez & Kehr, 2017). Because of the limited ecological information on the distribution of Iranian aquatic beetles, the objective of this study was to investigate the impact of environmental factors, including water pH, WT, AT and EC, on the distribution and diversity of aquatic beetles in Borujen and Lordegan as two towns of Chaharmahal and Bakhtiari Province 62 km and 170 km south of Shahrekord, the capital of the province. Such two regions, including wetlands, lakes, and rivers, have ample water resources.

MATERIAL AND METHODS

Study area

One of Iran's 31 provinces, Chaharmahl and Bakhtiari, situated in southwestern Iran. It covers an area of 16532 km^2 and ranges from 31 ° 14'N to 32 ° 47'N to 51 ° 24'E to 59 ° 49'E. Because of high mountains and snowy heights, Chaharmahal and Bakhtiari are covered with snow in winter. In general, from mid-autumn to April, snow and rain start at high altitudes above 2000 m, covering a large area of the province. The volume of atmospheric rainfall is lower in low-lying areas where temperatures reach more than 40 degrees Celsius in summer. Thus the temperatures rise from north to south as the altitudes decrease. Around mid-November, the cold season begins and lasts four to five months. January and February are the coldest months of the year. This province's capital is Shahrekord, 2150 meters above sea level, the province's highest center and is therefore recognized as Iran's Roof (Fig. 1 & 2). Marshes, rivers, ponds, and streams were chosen from two major provincial towns, Brojen and Lordegan (Appendix 1).

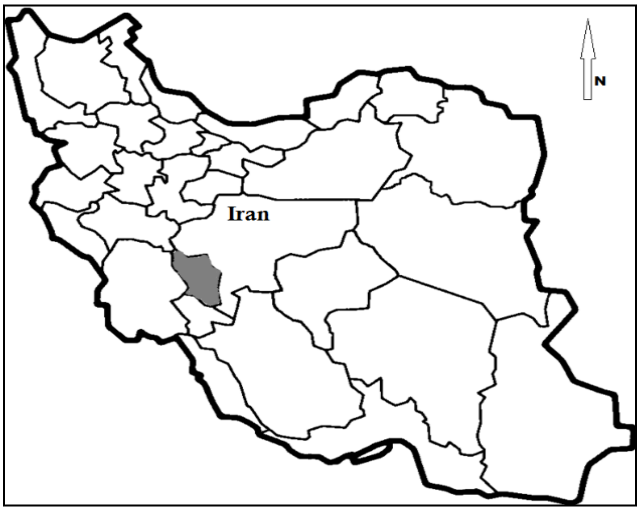

FIGURE 1. Location of Chaharmahl & Bakhtiari province within Iran.

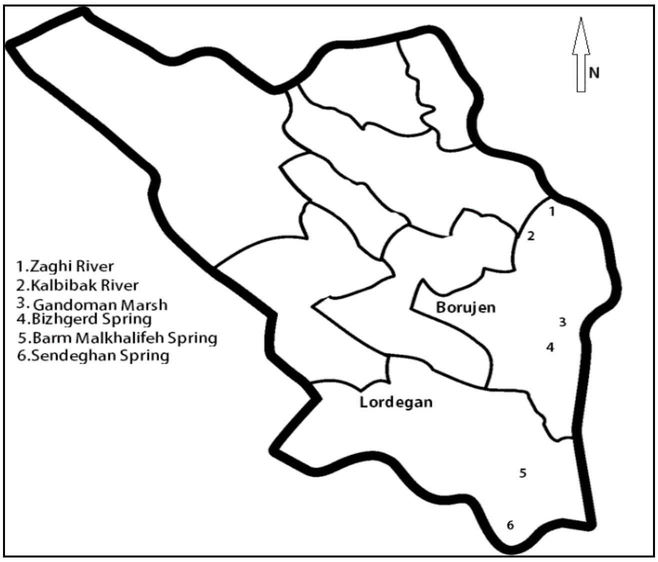

FIGURE 2. Location of 6 stations within Chaharmahl & Bakhtiari.

Sampling

Aquatic beetles were collected from six stations from September 2017 until July 2018 (Fig. 3). The net has been washed up and down along the water bodies' marginal vegetation. For further research, obtained samples were processed at 70% ethanol and moved to the laboratory.

Seasonally, ecological factors for each station were measured as follows: water pH (using a portable pH meter, Model 8601 AZ Taiwan), water EC (using a portable conductivity meter, Model 8301 AZ Taiwan) and WT and AT (using a mercury thermometer) (mean environmental factor values for six stations are provided in Appendix 2).

Identification

The specimens were identified using morphological literature, such as external taxonomic characteristics and external male genitalia (e.g. Zaitsev, 1953, Friday, 1988, Jach & Balk, 2003, Foster & Friday, 2011). All samples were deposited in the Zoological Museum, Shahrekord University (ZMSU).

Data analysis

In PAST, version 3, Canonical Correspondence Analysis (CCA) was introduced to analyze the effect of environmental factors including water pH, WT, air temperature (AT) and water EC on the population structure of aquatic beetles. In order to verify the relationship between each ecological factors incorporated with the aquatic Coleoptera distribution, a linear regression approach was applied. All statistical analysis was performed using version 16.0 of SPSS.

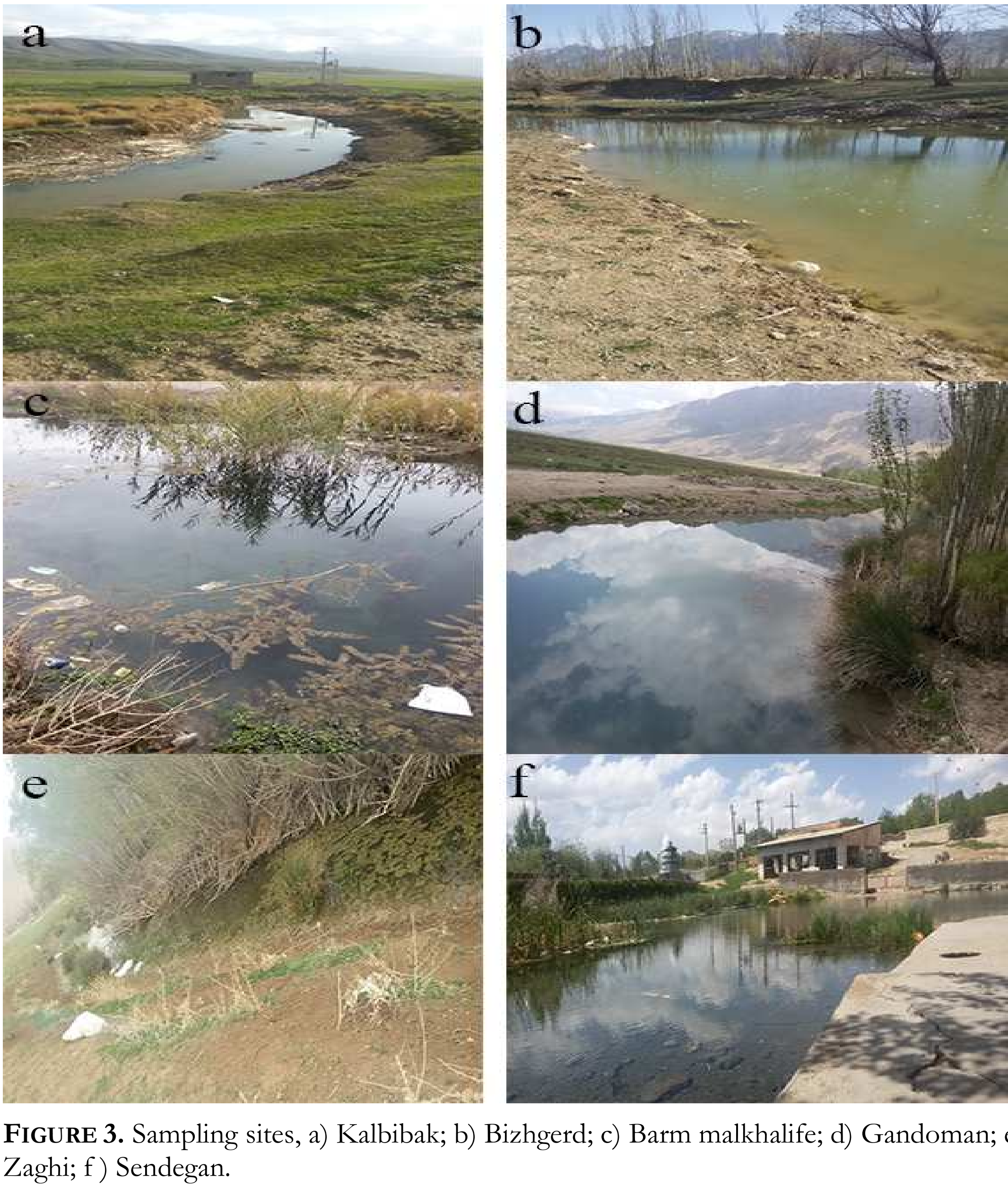

FIGURE 3. Sampling sites, a) Kalbibak; b) Bizhgerd; c) Barm malkhalife; d) Gandoman; e) Zaghi; f) Sendegan.

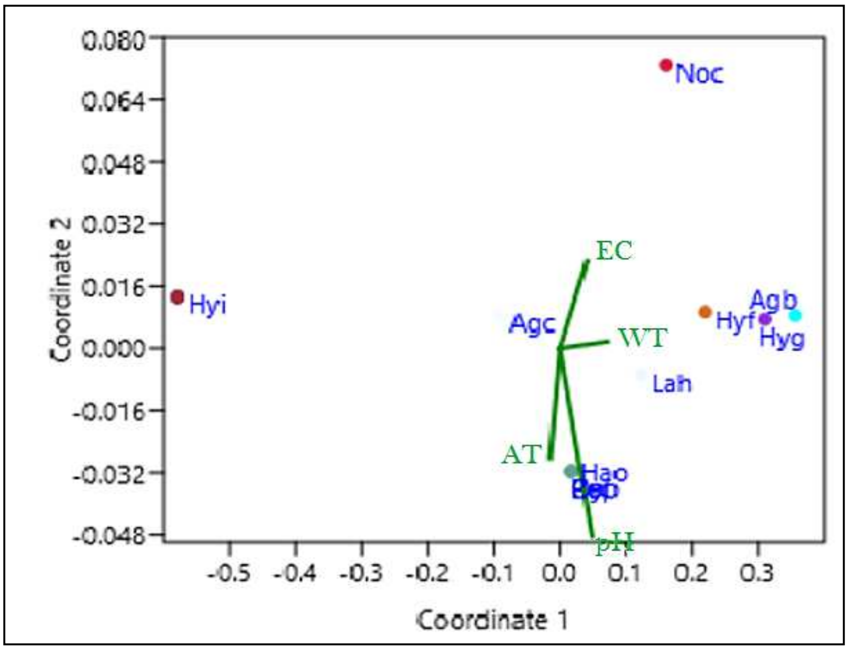

FIGURE 4.Ordination diagram of the species vs. environmental factors of canonical correspondence analysis.

RESULTS

A total number of 12 species belonging to 11 genera and 4 families were identified (Table 1). All species, except, *Laccophilus hyalinus*, are reported for the first time from Chaharmahal and Bakhtiari.
Species-environmental data set ordination analysis showed that four cultural variables (pH, EC, AT, and WT) were excellent predictors of habitat structure of the water beetle society. WT's value is much greater than other factors. The CCA-Biplots showed that the axes of this CCA had comparatively elevated individual values and the correlation between species and environment, indicating a close relationship between the chosen environmental factors and beetles. WT determined the primary environmental gradient (Fig. 4; axis 1). The second axis connected with pH. Closely correlated with EC was the third axis, and the fourth axis appeared to depict the gradient of AT. WT has been a significant determinant of the structure of the aquatic beetle society among chosen environmental factors.

Also, according to the results of linear regression analysis, it can be stated that the WT (with a correlation coefficient of 1.685) had the highest impact on the number of species. After that, the water pH (with a correlation coefficient of 0.822), water EC (with a correlation coefficient of 0.704) and AT (with a correlation coefficient of 0.390) had the highest effect. Therefore, the importance of ecological factors measured with species richness is as follows:

$$\text{WT} > \text{water pH} > \text{water EC} > \text{AT}$$

Finally, the following equation can be used to express the relation between species richness and ecological factors.

$$Y = -20.606 - 1.735\ \text{WT} + 2.466\ \text{water pH} + 0.054\ \text{water EC} + 0.291\ \text{AT}$$

TABLE 1. List of species.

Family	Genus	Species	Abbreviation	No.	locality
Dytiscidae	*Dytiscus*	*persicus*	Dyp	2	Gandoman
Dytiscidae	*Laccophilus*	*hyalinus*	Lah	1,4	Gandoman , Barm malkhalife
Dytiscidae	*Colymbetes*	*fuscus*	Cof	4	Gandoman
Dytiscidae	*Agabus*	*bipustulatus*	Agb	4,2, 8	Gandoman, Sendegan, Zaghi
Dytiscidae	*Agabus*	*conspersus*	Agc	9,9	Bizhgerd, Zaghi
Dytiscidae	*Nebrioporus*	*airumlus*	Nea	4	Bizhgerd
Dytiscidae	*Hydroglyphus*	*geminus*	Hyg	1,1	Zaghi, Barm malkhalife
Dytiscidae	*Hydroporus*	*inscitus*	Hdi	2	Bizhgerd
Haliplidae	*Peltodytes*	*caesus*	Pec	12	Gandoman
Haliplidae	*Haliplus*	*obliquus*	Hao	8	Gandoman
Hydrophilidae	*Hydrobius*	*fuscipes*	Hyf	4	Barm malkhalife
Noteridae	*Noterus*	*clavicornis*	Noc	17	Kalbibak

DISSCUSSION

This study investigated aquatic Coleopteran of Borujen and Lordegan**,** Chaharmahl & Bakhtiari province, Iran. From six stations surveyed, 11 genera and 4 families were found and identified. The most abundant families were Dytiscidae (51 samples), followed by Haliplidae (20 samples), Noteridae (17 samples), and Hydrophilidae (4 samples). Also, this study showed that *Agabus conspersus* and *Agabus bipustulatus* species were found in half of the stations where the samples were obtained. According to the results, the Gondoman marsh station is considered with the highest species richness.

The ecological information associated with each of the aquatic habitats plays an important role in the presence and distribution of aquatic Coleoptera (Akunal & Aslan, 2017). In the analyses carried out on abiotic factors, it was found that WT was the most influential factor in the aquatic Coleoptera distribution, followed by water pH, water EC and AT. In fact, WT is known to be the most effective factor in the development of aquatic insects so that the life cycle of aquatic insects is affected by the temperature cycles (Akunal & Aslan, 2017). In this study, the average WT measured was 16.45 ℃ and the adult specimens were found at temperatures ranging from 15-28 °C.

Also, the statistical results of this study indicate that water pH is an excellent indicator of the presence of these organisms in aquatic habitats. Similarly, (Dong *et al.,* 2014), (Verberk *et al*., 2001) and (Eyre *et al*., 1990) showed that water pH was the most important factor in the distribution of aquatic communities. The variation of all species is closely related to alkalinity and pH, and this factor is directly or indirectly related to the presence of aquatic Coleoptera. Aquatic organisms usually live at pH 5-9, while aquatic Coleoptera prefers more alkaline and neutral pH, but the safe pH level is different for each family (Akunal & Aslan, 2017). The mean of the water pH of water measured in this study was 7.75 and its range was 6.72-7.78. On the other hand, high alkalinity enhances decomposition by preventing the formation of organic acids, resulting in more food in the environment and the floating vegetation cover (Verberk *et al*., 2001). This is true for the members of the Haliplidae family, as in this study member of the family were found in alkaline pH and floating vegetation (pH: 7.49 - 7.89). In fact, vegetation, along with food and shelter, will increase their habitat diversity and provide new ecological niches for aquatic Coleoptera (Molnar *et al*., 2009).

Therefore, it can be concluded that among biotic factors, probably dense cover vegetation, water flow rate, natural habitat, and water elevation are the main factors influencing the distribution of aquatic Coleoptera (Gomezlutz & Kehr, 2017).

EC of water is the amount of salt soluble in water and is directly related to salinity. Salinity also directly or indirectly affects the water-soluble oxygen, pH, and nutritional factors (Akunal & Aslan, 2017). Some of these factors affect the distribution of aquatic Coleoptera. For example, the aquatic insect *Trichocorixa verticalis verticalis* can withstand high levels of water EC (Fenoglio *et al.*, 2016). In the present study, the least EC of water measured was 234.7 $\mu s.cm^{-1}$ and *Agabus bipustulatus* appeared to be more resistant to water EC in comparison with other samples because it occurred at two stations (Gandoman marsh and Zaghi River) with the highest levels of water EC. Salinity, as a physiological constraint (stressor), may affect distribution, abundance and diversity of inhabitants in aquatic ecosystems (Millán *et al.*, 2011; Arribas *et al.*, 2014).

For instance, hydraenids were found to be the most abundant coleopterans in natural saline streams of Spain (Millán *et al.*, 2011). Similarly, because of drought resistance and to avoid competition and risk of predation, hydrophilids evolved tolerance to salinity (Arribas *et al.*, 2014). In the present work, while the salinity levels were not measured in any of the stations, it can be stated that the species that live in standing waters have more tolerance to salinity than samples that are in the running waters (Cespedes *et al.*, 2013). Thus all specimens found in the stagnant water i.e. Gandoman marsh, including *Dystiscus persicus*, *Laccophilus hyalinus*, *Colymbetes fuscus*, *Agabus bipuspulatus*, *Peltodytes caecus,* and *Haliplus obliqus* are probably those species that can be tolerant to higher salinity (Larson, 1985; Lancaster & Scudder, 1987; Céspedes *et al.*, 2013).

Altitude is known to be an important factor for species distribution which influences the composition of aquatic insects. In this study, *Noterus calvicanus* was found at higher altitudes (e.g. Kalbibak river), while *Agabus bipustulaus* at lower altitudes (e.g. Sendegan spring). Similar patterns of species distributions were observed by (Touaylia *et al.*, 2011). The association with altitude may be related to the part of their life cycle affected by the altitude (Dodds & Hisaw, 1925). Other reasons could be specific microhabitat selection and dispersal abilities (Morris, 2003).

AT is another important factor in the distribution of aquatic Coleoptera. The seasonal pattern of temperature has a significant effect on the life cycle of many aquatic organisms (Sweeney *et al.*, 1986). The range of AT measured in this study was between 6.34℃ - 42.9℃ with a mean value of 20.66 ℃. Temperature fluctuations in this study did not differ significantly in different seasons and at different stations. However, aquatic Coleoptera is completely metamorphosed and has life stages of eggs, larvae, pupae and mature (Jardine, 2010). Thus, it is necessary to leave the water environment temporarily and return to the water environment after completing their life cycle. This shows that AT influences the developmental stages of aquatic insects and therefore indirectly controls their dispersal abilities.

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LITERATURE CITED

Akunal, A., Aslan, E.G., 2017. Ecological investigations on Hydrophilidae and Helophoridae (Coleoptera) specimens gathered from several water bodies of Western Turkey. Knowledge. Management. Aquatic. Ecosystem 418, 43.

Arribas, P., Andújar, C., Abellán, P., Velasco, J., Millán, A., Ribera, I., 2014. Tempo and mode of the multiple origins of salinity tolerance in a water beetle lineage. Molecular Ecology 23(2), 360-373.

Atamehr, A., Alaei, M., 2010. Two Aquatic Beetles Reported (Haliplidae: Coleoptera) from Azerbaijan. World Applied Sciences Journal 11(8), 918–923.

Cespedes V., Pallares S., Arribas P., Millan, A., Velasco, J., 2013. Water beetle tolerance to salinity and anionic composition and its relationship to habitat occupancy. Journal of Insect Physiology 59, 1076–1084.

Darilmaz, M., Incekara, U., Vafaei, R., 2013. Contributions to the knowledge of Iranian aquatic Adephaga (Coleoptera), Spixiana 36(1), 149–152.

Dodds, G.S., Hisaw, F.L., 1925. Ecological studies on aquatic insects, IV. Altitudinal range and zonation of mayflies, stoneflies, and caddisflies in the Coloradorockies. Ecology 6, 380–390.

Dong, B., Geng, Ch., Cai, Y., Ji, L., 2014. Aquatic Coleoptera response to environmental factors of Freshwater Ecosystems in Changbai Mountain, northeast China, Aquatic Ecosystem Health and Management 17(2), 171–178.

Eyre, M.D., Foster, N., Foster, A.P., 1990. Factors affecting the distribution of water beetle species assemblages in drains of eastern England. Journal of Applied Entomology 109(1990), 217-225.

Foster, G.N., Friday, L.E., 2011. Keys to the adults of the water beetles of Britain and Ireland, Royal Entomological Society, Vol.4 part 5 (2nd ed).

Friday, L.E., 1988. A key to the adults of British water beetles, Field Studies 7(1988), 1–151.

Gomezlutz, M.C., Kehr, A.I., 2017. A preliminary study of aquatic Coleoptera in temporary ponds and the Ecological variables influencing their richness and diversity. Journal of the Entomological Society of Argentina 76(3-4), 7-15.

Hosseinie, Sh., 1992a. A report on the aquatic Coleoptera of Bushehr, Iran. Latissimus, Newsletter of the Balfour-Browne Club, p. 10.

Hosseinie, Sh., 1992b. Report on the aquatic Coleoptera of Hormozgan, Iran. Latissimus, Balfour-Browne Club Newsletter, p. 22.

Hosseinie, Sh., 1994. A survey of the water Beetles of Khuzestan, Iran. Latissimus, Balfour-Browne Club Newsletter, p. 23.

Hosseinie, Sh., 1995a Report on the aquatic Coleoptera of Guilan, a province in the North of Iran. Latissimus, Balfour-Browne Club Newsletter, p. 11.

Hosseinie, Sh., 1995b. Water beetles in the Mazandaran Province, North of Iran. Latissimus, Balfour-Browne Club Newsletter, p. 20.

Jach, M.A., Balk, M., 2003. Key to adults of Chinese water beetle families. Water Beetles of China 3, 21–36.

Jardine B. (2010). Evolution & Phylogeny of Some Major Aquatic Radiations of Coleoptera. Aquatic Entomology 1-23.

Lancaster, J., Scudder, G.G.E., 1987. Aquatic Coleoptera and Hemiptera in some Canadian saline lakes: patterns in community structure. Canadian Journal of Zoology 65(6), 1383-1390.

Larson, R.J., 1985. Trophic ecology of gelatinous predators (Cnidaria and Ctenophora) in Saanich Inlet, Vancouver Island, British Columbia, Canada. Ph.D. thesis, University of Victor.

Millán, A., Velasco, J., Gutiérrez-Cánovas, C., Arribas, P., Picazo, F., Sánchez-Fernández, D., Abellán, P., 2011. Mediterranean saline streams in southeast Spain: what do we know? Journal of Arid Environments 75(12), pp.1352-1359.

Molnar, A., Csabai, Z., Tothmeresz, B., 2009. Influence of flooding and vegetation patterns on aquatic beetle diversity in a constructed wetland complex. The Society of Wetland Scientists 29(4), 1214-1223.

Morris, D.W., 2003. Toward an ecological synthesis: a case for habitat selection. Oecologia 136(1), 1-13.

Mousavi, A., Marjanyan, M.A., Kalashian, M.Yu. 2016. Contribution to the knowledge of the fauna of aquatic Adephaga (Coleoptera) of Mazandaran Province of Iran (Families Haliplidae and Dytiscidae), Humanity space International almanac 5, 18-21.

Nilsson, A.N., 2003. Dytiscidae, pp.35-78. In Catalogue of Palearctic Coleoptera (I. Lobl, A. Smetana Ed.). Vol. 1. Stenstrup: Apollo Books. 819p.

Ostovan, H., Niakan, J., 2004. Ecological and faunistic study on aquatic Coleoptera in South and North of Parishan Lake. Journal of Agricultural Sciences 4 (10), 93–116.

Sánchez-Fernández, D., Abellán, P., Mellado, A., Velasco, J. and Millán, A., 2006. Are water beetles good indicators of biodiversity in Mediterranean aquatic ecosystems? The case of the Segura river basin (SE Spain). Biodiversity & Conservation, 15(14), 4507-4520.

Segura, M.O., Fonseca-Gessner, A.A., Tanaka, M.O., 2007. Composition and distribution of aquatic Coleoptera (Insecta) in low-order streams in the state of São Paulo, Brazil: influence of environmental factors. Acta Limnol. Bras 19(3), 247-256.

Short, A.E.Z., 2018. Systematics of aquatic beetles (Coleoptera): current state and future directions. Systematic Entomology 43(1), pp.1-18.

Sweeney, B.W., Vannote, R.L., Dodds, P.J., 1986. Effects of temperature and food quality on growth and development of a mayfly, Leptophlebia intermedia. Canadian Journal of Fisheries and Aquatic Sciences 43(1), 12-18.

Touaylia, S., Garrido, J., Bejaqui, M., Boumaiza, M., 2011. Altitudinal Distribution of Aquatic Beetles (Coleoptera) in Northern Tunisia: Relationship between Species Richness and Altitude. The Coleopterists Bulletin 65(1), 53–62.

Vafaei, R., Ostovan, H., Incekara, U., Pesic, V., 2007. Faunistic study of the aquatic beetles (Coleoptera: Polyphaga) of Markazi Province (Central Iran) with new records. Archives of Biological Sciences 59(3), 239–242.

Vafaei, R., Darilmaz M.C., Nazari E., Incekara U., Piazak N., 2009. Contributions to the knowledge of Iranian aquatic Coleoptera fauna (Dytiscidae, Gyrinidae, Helophoridae and Hydrophilidae) with new records and notes on the rare species Coleostoma transcaspicum Reitter, 1906. Acta Entomologica Serbica 14(1), 101-107.

Vanvondel, B.J., 2003. Haliplidae.P. 30-33. In: Catalogue of Palearctic Coleoptera (I. Lobl, A. Smetana eds.). Vol. 1. Stenstrup: Apollo Books. 819p.

Vanvondel, B.J., Ostovan, H., Ghahari, H., 2017. An annotated checklist of Iranian Myxophaga (Hydroscaphidae, Sphaeriusidae) and Adephaga (Gyrinidae, Haliplidae, Noteridae, and Rhysodidae) (Insecta: Coleoptera). Zootaxa 4216(3), 225–246.

Verberk, W., van Duinen, G., Peeters, T., Esselink, H., 2001. Importance of variation in water-types for water beetle fauna (Coleoptera) in Korenburgerveen, a bog remnant in the Netherlands. Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 12, 121-128.

Zaitsev, F.A., 1972. Fauna of the USSR (Fauna SSSR) Coleoptera. Volume IV. The Smithsonian Institution and the national science foundation, Washington, D.C., 401 pp.

Appendix 1. Geographic information for each station

	Locality	Latitude	Longitude	Altitude
1	Zaghi River	32°02'54"N	51°06'35"E	2136 m
2	Kalbibak River	31°53'40" N	50°53'16" E	2278 m
3	Gandoman Marsh	31°51'05" N	51°05'34" E	2219 m
4	Bizhgerd Spring	31°46'55" N	51°11'35" E	2216 m
5	Barm malkhalife Spring	31°17'21" N	51°15'58" E	1744 m
6	Sendegan Spring	31°15'35" N	51°17'00" E	1739 m

Appendix 2. Mean values of environmental factors at six-station.

Parameter	Kalbibak	Zaghi	Gandoman	Bizhgerd	Barm Malkhalife	Sendegan
pH of water	7	7.2	7.66	7.57	8.3	8.57
EC of water	465.45	478.95	456.25	424.95	468	495.65
AT	16.15	16.95	19.9	20.85	22.27	17.25
WT	14.74	14.49	13.14	13.97	17.72	16.98