A scientific report on Ephemeroptera of Jajrood River, Northern Iran

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Abstract
Mayflies, order Ephemeroptera compose one of the main habitants of all the aqua systems around the world, which has valuable roles in several food chains. In this study, species diversity of Ephemeroptera in Jajrood River (Hajiabad, Saeidabad, and Khojir areas), eastern Tehran Province, was studied through spring-summer, 2016. Samples collected weekly and kept in Ethanol 80% for taxonomic identification. One hundred forty-nine samples belonged to 17 species, under 7 genera in 4 families (Baetidae, Heptageniidae, Habrophlebiidae, and Isonychiidae) were collected. The majority of species abundance (45.63%) obtained from Khojir, although Hajiabad with 11 different species showed a more diverse collection for Ephemeroptera. Among the collected species, Heptagenia lateralis, Isonychia shima, Habrophlebia lauta, Labiobaetis arebalinus, Labiobaetis potamoticus, Labiobaetis glaucus, and Baetis atlanticus were reported for the first time for Iran fauna and Baetis fauscatus and Baetis rhodani were the most common species. According to diversity indices, Khojir area along the River showed higher species collection. Knowledge of the species diversity in aqua systems in urban areas like Jajrood River would lead to new insight into ecosystem preservation and better management decisions.

Keywords: Ephemeroptera, Jajrood River, species diversity

Introduction
Ephemeroptera (Mayflies), as a rich-species class, has a worldwide distribution with a great collection for the Iran fauna. These unique species compose one of the primary organisms of all the aquatic systems around the world. Through previous studies on the species variation of Ephemeroptera in Iran, 46 species belonging to 25 genera have been reported from different parts of the country (Bojkova et al., 2018). A recent checklist of Iranian Ephemeroptera showed that the vast majority of collected species were limited to the northern part of Iran (Alborz Mountains and its surroundings). Through a comprehensive study on the aquatic species of Iran in addition to some parts of neighboring countries such as Iraq, Azerbaijan, Turkemanestan, Afghaniatan and Pakistan, Momhammadian (2005) showed that Ephemeroptera could be one of the most abundant and diversified groups of the aquatic residents which could not be a reliable resource for Iranian Ephemeroptera. Moreover, most of the studies on Ephemeroptera in Iran have focused on the ecological features of the aquatic habitats and the water quality effects; and reported this class as the main group of benthic macro-invertebrates.

In a comprehensive review of the previous studies about the benthic macro-invertebrates, Sharifinia (2015) reported 37 Ephemeroptera samples from Iranian Rivers, which were identified to species or genus level. Shayeghi et al. (2014) assessed the fauna of aquatic insects.
for possible use for Malaria vector control in the Karaj River. They reported Ephemeroptera as one of the three orders live in the area. The similar report was admitted in the other studies in different parts of the country such as east of Golestan Province (Eyidozehi et al., 2014), Zayandehrood River in Isfahan Province (Ghane, 2013), Cheshmeh Kileh in Guilan Province (Abbaspour et al., 2013a, 2013b) and Mohammad Abad River in Golestan Province (Farhangi and Teymouri Yansari, 2011). Kamali and Tatina (2010) presented Ephemeroptera as the most abundant taxon in Lamir River in the Talesh area, Guilan Province. Some studies focused on the taxon classification of species and genus levels. Mousavi and Hakobyan (2017) studied the fauna of Ephemeroptera, Plecoptera, and Trichoptera from some water bodies in Mazandaran Province and reported ten species in 5 genera including Cloeon sp, Oligoneuriella, Epeorus, Ephemeraella and Caenis belonging to 5 families. Sharifinia et al. (2016) evaluated the pollution level in Shahrood River in Qazvin Province, and its effect on the reported some genera, including Ameletus, Baetis, Ecdyonurus, Cinygmula, and Serinitella. Ebrahimi et al. (2014) recorded five Ephemeroptera species in four families, including Baetidae, Caenidae, Ecdyonuridae, and Ephemerellidae for Zayandehrood River. Farasat and Sharifi (2014) reported three genera, including Baetis, Ephemeraella, and Maccaffertium for macro-invertebrates benthic fauna of Kavat Stream, Western Iran. Mahboobi Soofiani (2012) studied the macro-invertebrates of Zayandehrood River and reported 15 genera belonging to 7 families. Jacobus et al. (2009) reported Serratella brevicauda and S. elissa for the first time for Iran fauna, which was published from China, too. Poorali Darestani (2009) reported three genera of Baetis, Cloeon, and Caenis from Cheshmeh Ali in the Damghan area. Dehghani et al. (2004) studied the aquatic insects of the Kashan area and reported that Ephemeroptera compromised 7% of the total samples, which were mostly included of two genera, Baetis and Heptagenia.

In a unique study in Jajrood River, 42% of the total fauna population belonged to Ephemeroptera in five families, Baetidae, Heptageniidae, Caenidae, Leptophlebiidae, and Oligoneuriidae and 7 genera, Baetis, Cloeon, Epeorus, Rhithrogena, Caenis, Paraleptophlebia and Lachlania (Amri et al. 2014), but according to Bojkova (2018), as there was reported many species known for Nearctic and Neotropic Regions, the occurrence of these species should be excluded from Iran fauna. It is expected that Iran, as the second-largest country of the Middle East after Saudi Arabia, has a rich collection of the Ephemeroptera fauna. Iran should be viewed as a specific transitory zone hosting West Palaearctic (European) and Caucasian elements of fauna on one hand and Central Asian or even Oriental faunal elements on the other being undoubtedly worth of the detailed and extensive study (Bojkova, 2018). There is a great need to identify Ephemeroptera species richness throughout the country, and this study was conducted to determine Ephemeroptera fauna in Jajrood River, east of Tehran Province.

**Findings**

In this study, a totally of 149 samples were collected and classified into 17 species belonging to 7 genera under three different families of Ephemeroptera from Jajrood River. Among the collected samples, 7 species, Heptagenia lateralis, Isychia shima, Habrophlebia lauta, Labiobaetis atrebalinus, Labiobaetis potamoticus, Labiobaetis glaucus, and Baetisat lanticus were reported for the first time for Iran fauna. However, they have been previously reported at the genus level from Iran that will be noticed separately for each species. All of the collected species are as the following:

**Heptageniidae:**

Heptagenia lateralis McDunnough, 1924

The genus Heptagenia has been already
reported from Iran in Karaj River (Shayeghi et al., 2014), Zayandehrud River in Isfahan (Ebrahimi et al., 2014; Ghane, 2013; Ebrahimnezhad and Nikoo, 2004) and Shamrood River in Guilan (Rahimibashar et al., 2015). The species has previously reported from Turkey (Salur et al., 2016; Kazanci and Turkmen, 2012; Tanatmis, 2002), Black sea basin (Petrovic et al., 2015). The species was collected from Hajiabad in Jajrood River (Table 1), and this is its first report for the Iran fauna.

Isonychidae:
*Isonychia shima* Matsumura, 1931
This Japanese species have been classified as *Prionoides shima* and recently transferred to *Isonychia* species (Tiunova et al., 2004). The species was collected from Hajiabad in the Jajrood River (Table 1). This is the first report of this species from Iran.

Habrophlebiidae:
*Habrophlebia lauta* McLachlan, 1884
This Palearctic species has been recorded from Turkey, Europe (Haybach and Malzacher, 2002), and North Africa and recently was reported from Gilan Province, Iran (Bojkova et al., 2018). Ebrahimnezhad and Nikoo (2004) reported the genus *Habrophlebia* from Marbor River, Isfahan Province. Aydinli (2017) reported the species from black sea area in Turkey. This species was collected for the Iranian fauna from Hajiabad in Jajrood River (Table 1).

Baetidae:
*Labiobaetis atrebalinus* Eaton, 1870
The species has been collected from Turkey (Aydinli and Ertorun., 2015). The genus has been reported from Khuzestan Province in Iran (Sroka et al., 2019). This is the first report of the species from Iran, in Khojir sampling points in Jajrood River (Table 1).

*Labiobaetis potamoticus* Gattolliat and Al Dhafer, 2018
The species has been reported from Saudi Arabia (Gattolliat et al., 2018). The genus has been reported from Khuzestan Province in Iran (Sroka et al., 2019). This is the first report of the species from Iran, in Khojir sampling points in Jajrood River (Table 1).

*Labiobaetis glaucus*, Agnew 1961
These Palearctic species have been reported from Saudi Arabia (Gattolliat et al., 2018). The genus has been reported from Khuzestan Province in Iran (Sroka et al., 2019). This is the first report of the species from Iran, Khojir in Jajrood River (Table 1).

*Centroptillum luteolum*, Otto Friedrich Müller, 1776
This species has been collected from Turkey (Aydinli and Ertorun, 2015), Germany (Haybach and Malzacher, 2002), and Serbia (Petrovic et al., 2015). This species was previously reported from Iran, but the exact sampling area did not mention (Mohammadian, 2005). This was collected from Hajiabad, Khojir, and Saeidabad sampling point in the Jajrood River (Table 1).

*Procloeon capsicum* sp.n.
This species has been referred to as *Pseudocentroptillum capsicum* (Bojkva et al., 2018) and reported from Guilan Province. In this study, just one sample was collected belonged to this species from the Hajiabad point (Table 1).

*Baetis barokianus*, Thomas and Dia1984
This Mediterranean species was previously reported from Cyprus (Godunko et al., 2017), Lebanon (Godunku et al., 2017) and Iran, Siahrud River in Roudbar country, and Sardar Jangal district from Masouleh city (Bojkova et al., 2018). In this study, the samples collected from Hajiabad and Khojir have belonged to this species (Table 1).

*Baetis rhodani*, Pictet, 1843
The species is widely distributed in the western Palearctic region and has been reported from different countries in the Middle East and Mediterranean areas such as Turkey (Aydinli, 2017; Aydinli and Ertorun, 2015; Turkmen and Kazanci, 2013) and Europe like Germany.
(Haybach and Malzacher, 2002) and Serbia (Petrovic et al., 2015). In Iran, it was collected from the bottom substrate of Zarrinehrud River in the west of Azarbaijan Province and Karaj River in Alborz Province (referred to Bojkova et al., 2018); in addition to the previous reports, in the last Ephemeropteran study in Iran, it was collected from Guilan and Ardabil Provinces, too. Ebrahimi et al. (2014) reported B. rhodani from the Zayandehrud River in Isfahan. In this study, the species was reported from all the sampling points, mostly from Saeidabad (Table 1).

**Baetis fuscatus**, Linnaeus 1761
This Transpalaeartic or Holarctic species was collected as a new record from Guilan Province (Bojkova et al., 2018). It was from different parts of the world such as Turkey (Turkmen and Kazancı, 2013; Aydinli and Ertorun, 2015 and Aydinli, 2017), Germany (Haybach and Malzacher, 2002) and Serbia (Petrovic et al., 2015). In this study, the species was reported from Hajiabad and Khojir sampling areas, mostly in Hajiabad (Table 1).

**Baetis atlanticus** Soldán and Godunko 2006
This species was collected first in Portugal as a new species and was known as conspecific with B. rhodani (Soldán and Godunko, 2006). Six samples of the species were collected from the Khojir sampling point in two sampling times, and this is the first report of the species for Iran fauna (Table 1).

**Baetis (Nigrobaetis) muticus** Linnaeus 1758
The species mainly belonged to Kazakhstan and was reported from the black sea area in Turkey (Aydinli, 2017). In Iran, it was reported previously from Mazandaran Province in Chatan River, Guilan Province, and Ardabil Province (Bojkova et al., 2018). In this study, Two samples of the species were collected from the Jajrood River (Table 1).

**Baetis gemellus** Eaton 1885
This species has been collected from the eastern part of the Black Sea in Turkey (Turkmen and Kazancı, 2013), and similar samples to this species have been previously reported from Ardebil and Guilan Provinces of Iran which were categorized as *Baetis vadimi*. This is the first report of the species in Iran. In this study, samples belonging to this species was collected from the Khojir point (Table 1).

**Baetis lutheri** Muller-Liebenau 1967
This species is widely distributed from Europe to the Caspian, Turkey (Kazancı and Türkmen 2012; Turkmen and Kazancı, 2013; Aydinli and Ertorun, 2015; Salur et al. 2016; Aydinli, 2017), Germany (Haybach and Malzacher, 2002) and Iraq (Al-Zubaidi et al. 1987) and recently reported from Guilan and Ardebil Provinces in Iran (Bojkova et al., 2018). Khojir and Saeidabad had five samples of this species (Table 1).

**Baetis melanonyx** Pictet 1843
This species has been reported from Germany (Haybach and Malzacher, 2002), and previously it was collected from Sefidrud River in Roudbar County (Godunko et al., 2017), but it was not reported officially. In this study, larvae of this species were collected from Khojir and Hajiabad (Table 1).

**Baetis tricaudatus**, Dodds 1923
The species was reported from Jajrood River (Amri et al., 2014). In this study, 3 larvae belonging to this species were collected from the Hajiabad sampling point (Table 1).
Table 1. Samples collected from different sampling dates with notification of their sampling locations and the species frequency (No.) with frequency percentage

<table>
<thead>
<tr>
<th>Species</th>
<th>Sampling time through spring and summer</th>
<th>Total samples collected</th>
<th>Frequency percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April</td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>Heptagenia lateralis</td>
<td>3 Hajiabad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isonychia shima</td>
<td>1 Hajiabad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habrophlebia lauta</td>
<td>1 Hajiabad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labiobaetis arebalinus</td>
<td>6 Saeidabad</td>
<td>4 Hajiabad</td>
<td></td>
</tr>
<tr>
<td>Labiobaetis potomaticus</td>
<td>1 Khojir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labiobaetis glaucus</td>
<td>6 Khojir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudocentroptiloides capiscum</td>
<td>1 Hajiabad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centroptillum luteolum</td>
<td>3 Saeidabad</td>
<td>1 Hajiabad</td>
<td>1 Khojir</td>
</tr>
<tr>
<td>Baetis barokianus</td>
<td>1 Khojir</td>
<td>1 Hajiabad</td>
<td></td>
</tr>
<tr>
<td>Baetis rhodani</td>
<td>1 Saeidabad</td>
<td>19 Saeidabad</td>
<td>1 Hajiabr</td>
</tr>
<tr>
<td>Baetis fascatus</td>
<td>1 Hajiabad</td>
<td>3 Khojir</td>
<td>24 Hajiadb</td>
</tr>
<tr>
<td>Baetis atlanticus</td>
<td>3 Khojir</td>
<td>3 Khojir</td>
<td></td>
</tr>
<tr>
<td>Baetis muticus</td>
<td>2 Saeidabad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetis gemellus</td>
<td>1 Khojir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetis lutheri</td>
<td>1 Khojir</td>
<td>4 Saeidabad</td>
<td></td>
</tr>
<tr>
<td>Baetis melanonyx</td>
<td>6 Khojir</td>
<td>3 Hajiadb</td>
<td></td>
</tr>
<tr>
<td>Baetis tricaudatus</td>
<td>3 Hajiadb</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>SUM</td>
<td>16</td>
<td>68</td>
<td>45</td>
</tr>
</tbody>
</table>

As can be seen in Table 1, most of the samples were collected through May–June. Larvae were found in all the sampling points with varied diversity and abundance. But decreasing the frequency of the collected samples could be observed through summer months, especially in July, which could be due to high temperatures or high concentrations of water pollution or predation by fish or other aquatic predators.

Table 2. Shannon and Simpson indices for the sampling areas

<table>
<thead>
<tr>
<th>Sampling area</th>
<th>Species No.</th>
<th>Species frequency (%)</th>
<th>(Simpson Index)D</th>
<th>(Shannon Index)H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hajiabad</td>
<td>11</td>
<td>29.53</td>
<td>3.064</td>
<td>1.525</td>
</tr>
<tr>
<td>Khojir</td>
<td>10</td>
<td>24.83</td>
<td>7.1994</td>
<td>1.762</td>
</tr>
<tr>
<td>Saeidabad</td>
<td>5</td>
<td>45.63</td>
<td>2.909</td>
<td>1.275</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Diversity indices are used to determine the species diversity in a given area and it could be used to compare species diversity among similar areas. As can be seen in Table 2, Shannon and Simpson's indices revealed different results for the sampling area. According to the Shannon index, Khojir had the most abundant species diversity, and the highest calculated H index (1.762) would be discussed regarding the partial high Simpson index (7.1994) with ten species. On the other hand, Saedabad had the lowest Simpson index as (2.909) parallel with the lowest Shannon index (1.275) composing high quantity (45.63%) of all the collected samples. Sorensen's Coefficient was calculated for two pair of areas separately, CC was calculated for Khojir and Saedabad areas as 0.434, for Hajiabad and Saedabad as 0.285 and Hajiabad and Khojir as 0.285 (Table 2).

According to the results, 17 species were collected from three areas along Jajrood River in three sampling areas Saedabad, Hajiabad, and Khojir. According to the recent review studies, a great checklist of 46 species belonging to 25 genera of Iranian Ephemeroptera has been reported (Bojkova et al., 2018). Other similar studies showed the great importance of Ephemeroptera biodiversity in different aqua systems of Iran such as rivers in Lar Park (Salavatian et al., 2011), Zayandehrood River (Mahboobi Soofiani et al., 2012), Shadegan Lagoon (Nasirian et al., 2014) and Jajrood River (Amri et al., 2014). Several studies mentioned that water pollution, water depth and water warmth would be the main factors affecting the macroorganisms of aqua systems (Mahboobi Soofiani et al., 2012; Shalbaf et al., 2012; Nasirian et al., 2014; Sharifinia et al., 2016). So besides the water pollution, the abiotic factors of the aqua-system should be considered as the effective factors on Ephemeroptera diversity and abundance.

The results of the present study showed that Jajrood River in the eastern part of Tehran Province could be a valuable reservoir for Ephemeroptera species, which is needed to be reserved and protected against chemical pollution from urban areas along the River. Khojir area showed more Ephemeroptera species collection that would be due to less infection or higher organic materials in water. Sampling through Jajrood River added seven new species to the Iran fauna, which would be used in future studies about environmental protection and fish farming.

References
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