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Use of the Aquatic Mayfly (Insecta: Ephemeroptera) as Environmental Bio-Indicator in Jordan

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ABSTRACT

In this article, aquatic mayflies from several wadis in Jordan are studied on their potential use as environmental indicators. Nine species of mayfly were observed in the studied wadis, encompassing *Baetis monnerati*, *Cheleocloeon soldani*, *Cloeon vanharteni*, *Cloeon gr simile*, *Baetis pacis*, *Nigrobaetis vuatazi*, *Choroterpes ortali*, *Caenis antoniae*, *and Caenis macrura*. Among Baetidae species, *Baetis monnerati* was more abundant and seems to be the most tolerant species to pollution. In addition, it tolerates water salinities of up to reach 1.000 µS/cm. Contrastingly, *Baetis pacis* was also observed to be the most intolerant species to pollution. The species survives in very good freshwater quality that makes it a perfect indicator of very clean water. *Cloeon vanharteni* live in brackish lentic habitat with dense vegetation. This species was found together with *Cloeon gr simile*. Both can tolerate salty water, with salinities of up to 16.000 µS/cm and tolerate in addition, organically polluted water. Furthermore, *Choroterpes ortali* was found to colonize slightly saline, mineralized and polluted water like *Nigrobaetis vuatazi* and *Cheleocloeon soldani*.*Caenis macrura* indicates clean to moderate polluted while *Caenis antoniae* is less pollution-tolerant, and only found in clean to weakly polluted environments. The study concludes that Baetidae mayflies can serve as powerful indicators of the environmental conditions than other mayfly families in Jordan.

1. INTRODUCTION

Aquatic mayflies are an ecologically important insect group which represent vital component of the aquatic macroinvertebrate biomass and production in both lotic and lentic water bodies such as rivers, ponds, streams and lakes during their nymph stage (immature form), while the adult stage, is aerial [1]. The existence of aquatic mayfly, like other organisms, depends mainly on the physical, biological and chemical properties of the water they live in. The mayfly group is known to respond, in a fast way, to changes in the environmental conditions. Therefore, the presence or absence of mayfly species can provide important clues about the environmental health status and of the aquatic system. This enables their use as bio-indicators of the environmental conditions and helps in water quality assessments [2-4]. Mayfly nymphs are strongly influenced by several environmental conditions, for example, Vilenica et al. [4] noted that the nymphal growth, embryonic development, and survival rate were affected by water temperature. Also other studies showed that mayflies are negatively associated with increasing conductivity and TDS of the aquatic system [5-7].

Mayflies have been widely investigated as bio indicators for fresh water and marine environments, because they are abundant, and diverse and their determination is rapid and of low-cost method. In addition, they are easily collected and distinguished from other aquatic macroinveratbrates [8-11].

Several studies on the use of mayfly as a valuable biological indicator for acidification, eutrophication, habitat degradation, temperature, heavy metals, nitrates and phosphorus enrichment, and salinity were carried out worldwide [12-16]. Locally, previous studies on mayfly's assemblages confirmed their use as effective bioindicators for environmental changes of freshwater systems in northern Jordan, as correlated to different environmental parameters such as salinity, pollution and trace elements [17-19].

Only some studies focused on the taxonomy of mayfly fauna of Jordan [20-23]. Malzacher [20] identified mayfly species in Israel and Jordan, while recently Gattolliat et al. [21] started to describe mayflies from Jordan and reported different species belonging to Baetidae, Caenidae and Leptophlebiidae families, which live in the central parts of Jordan. They reported seven species such as *Nigrobaetis vuatazi* Gattolliat & Sartori n.sp, *Baetis monnerati* Gattolliat & Sartori n.sp., *Procloeon pennulatum* (Eaton, 1870), *Cloeon dipterum* (Linnaeus, 1761), *Caenis antoniae* Malzacher, 1992, *Caenis parabrevipes* Malzacher, 1992, *Choroterpes (Euthraulus) ortali* Sartori, 1992.

Recently, Alhejoj et al. [23] have defined four species of mayfly for use as bioindicators, namely, *Cheleocloeon soldani* Gattolliat & Sartori, 2008, *Cloeon vanharteni* Gattolliat & Sartori, 2008, *Baetis pacis* Yanai & Gattolliat, 2018, and *Caenis macrura* Stephens, 1835, which were collected from different Jordanian waterbodies. Additionally, they provided a mayfly checklist of Jordan, which deliver an identification key to the larval stages.

The objective of this study is to identify aquatic mayfly species in Jordan's relevant surface water sources in order to

use this insect group as indicator of environmental conditions. The study is a part of several studies aiming at continuing the older studies of Alhejoj et al. [18] to include more mayfly's species and add other locations of water bodies in Jordan. In addition, it aims at investigating the relationship between the mayfly assemblages, water physicochemical parameters and other associated aquatic organisms.

2. METHODOLOGY

The applied methodology is summarized in the use aquatic mayfly and the water qualities they live in as an indicator on the environmental conditions. Mayfly nymphs were collected together with water samples from 21 sites distributed from northern to southern Jordan as follows: Wadi Arab, Wadi Rajib, Zarqa River, Wadi Hisban, Karama area, Wadi Mujib, Wadi Atun, Wadi Ibn Hamad, Wadi Karak, and Wadi Hasa (Figure 1). These sites consist of running water except Karama site. Generally, that water originates in the highlands east of the Jordan Rift Valley and flows down to the low lands, below sea level, in the Jordan Valley and the Dead Sea, and Wadi Araba areas. The altitudes of the sites range from around 350 m below sea level. in Wadi Hisban to more than 900 masl in mountainous areas.

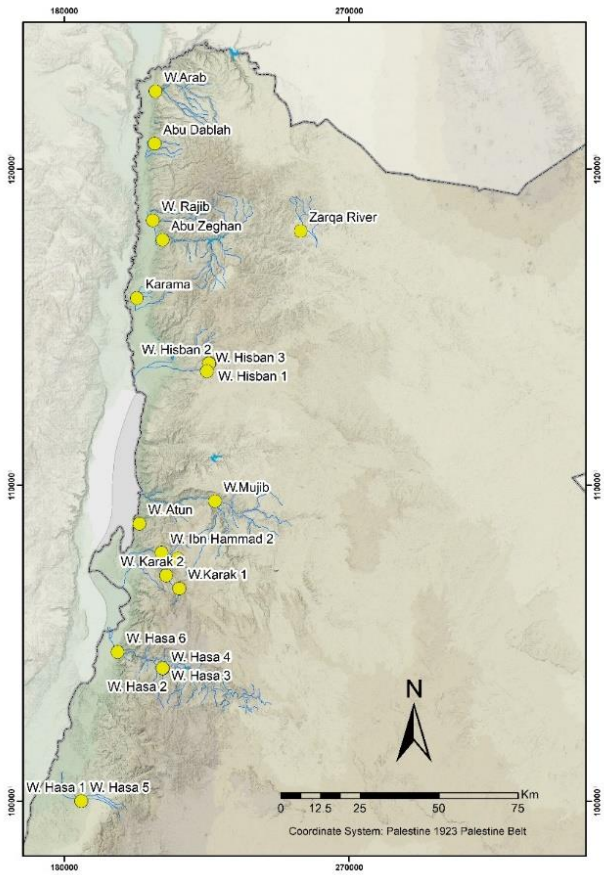

Figure 1. Locations of the study sites in the area extending from Wadi Arab in north Jordan to Wadi Hasa in south Jordan

Within this framework, both fresh and brackish, regular and thermal, clean and polluted, lotic and lentic, fast and slow flowing, normal and mineralized waters were sampled from, dry warm and cold wet environments. The substrates were mainly composed of fine to coarse clastic sediments and aquatic vegetation.

Fieldwork and measurements to study the wadis from the aspects of water type, habitat, topography etc. were performed through numerous field campaigns during the different seasons of the year. At each site, mayflies and water were sampled for laboratory analyses, which in included: alkalinity, hardness, NO_3-N, PO_4-P, Cl^-, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). In the field water electric water conductivity, pH and temperature were measured using WTW-field equipment.

Water analyses were carried out according to the standard methods of the United States Geological Survey. Mayfly nymphs were sampled during February to May (late winter to spring) from 2019 to 2022 using a sieve of 500 µm and benthos hand net. Those aquatic mayflies that cling to rocks, gravels, aquatic vegetation and often found under the rocks were manually collected by brushing them with the hand or with a fine brush. Sampled mayfly nymphs were stored in 80% ethanol and packed for analyzed in the laboratory.

The freshly collected mayfly nymphs were sorted and documented under a S6 D Leica stereomicroscope with magnification of 6.3– 40 x that is connected to a digital camera and Leica DM750 microscope. Prof. Jean-Luc Gattolliat at the Museum of Zoology, Switzerland, carried out the identification of mayfly to species level.

3. FIELD OBSERVATIONS AND DISCUSSION

In this study, we evaluate the water quality and other environmental parameters by using aquatic mayflies which are found in most conceivable habitat in both fresh and brackish, stagnant and flowing, normal (18-230C in winter and 22 to 350Cin summer) and thermal mineralized (more 450C), and polluted water. Different species of mayflies occur in these waterbodies throughout Jordan. They belong to Baetidae, Caenidae, Leptophlebiidae. Member of Oligoneuriidae, Potamanthidae and Prosopistomatidae families are not reported from Jordan. Among Jordanian mayflies Baetidae is the most common in addition to diverse other species represented by *Baetis monnerati*, *Cheleocloeon soldani*, *Cloeon vanharteni*, *Baetis pacis*, *Nigrobaetis vuatazi*, *Procloeon pennulatum* and *Cloeon dipterum*. *Baetis monnerati*, was firstly reported and described from Jordan by Gattolliat et al. [21]. *Baetis monnerati* is a widespread species, which exists in most running freshwater across Jordan**.** It lives under different freshwater environmental conditions in wet cold to dry warm, slow to fast running, clean to polluted water and in fine or coarse substrate and aquatic vegetation as they occur in Wadi Arab, Wadi Rajib, Zarqa River, Wadi Hisban,Wadi Mujib, Wadi Ibn Hamad, Wadi Karak, and Wadi Hasa and other localities (Table 1). From the study observations, we found this species in both clean water (e.g., Wadi Arab and Wadi Hisban) and organically polluted waters (Wadi Karak downstream the waste water treatment plant, hence forth WTP). The treated wastewater of Karak WTP mixes with the water in Wadi Karak (site 15) and forms a fast running, brownish water with a salinity of about 655 µS/cm. The wadi has a gravel bottom substrate, where dense occurrences of *Baetis monnerati* species were found (Table 2).

Additionally, in Zarqa River not far from Khirbat Al-Samra WTP (site 4), the treated wastewater mixes with the stream water. Here, only *Baetis monnerati* species of mayfly was

observed associated with tubfix worms (Family Tubificidae) and *Physa acuta* (Class Gastropoda). Also, this species lives in slow running water of Wadi Hasa in the downstream area near Dead Sea and in the fast running water of Wadi Majhoul near Tafilah and other locations. The substrate in the mentioned sites is coarse-grained or is covered by aquatic vegetation. *Baetis monnerati* is documented in a small creek close to Wadi Mujib Dam (site 11), associated with eutrophic water and dense occurrences of algal mats (Table 3). This species disappeared totally in some locations along the studied wadis, which is related to increases in the concentrations of the physiochemical environmental factors of the water systems, including salinity, trace elements, and temperature. In Wadi Hasa stream near Tannur Dam, *Baetis monnerati* were absent and declines in the other macroinvertebrates community registered. Only observed was larval black flies (Family Simuliidae) and boatman insect (Order Hemiptera) with microbes, seemingly due to increasing salinity, which reaches 1450 µS/cm. "The high salinity in this location originates from the dissolution of evaporates, especially, gypsum originating from the country rocks in that area, where gypsum mineral is being mined."

Table 1. Coordinates, occurrences of mayfly species and, summary of their habitats in the studied sites

	Location	Coordinates	Species	Habitats
1	W.Arab	32.6148°N, 035.6246°E	*Baetis monnerati, Caenis macrura*	Moderate fresh running water with stony substrates
2	Abu Dablah thermal spring	32.462883°N, 35.622541°E	-	Thermal mineral spring water
3	W. Rajib	32.2465°N, 035.6135°E	*Baetis monnerati, Caenis macrura*	Moderate freshwater running with stony substrates
4	Zarqa River	32.149688°N, 36.136117°E	*Baetis monnerati*	Brownish turbid, moderate to slow moving freshwater with coarse and fine substrates
5	Abu Zeghan	32.184974°N, 35.632181°E	*Baetis monnerati*	Moderate to slow moving freshwater with coarse and fine substrates
6	Karama	32.025°N, 035.559°E	*Cloeon vanharteni, Cloeon gr simile*	Brackish pond with muddy bottom and surrounded by emergent reeds
7	Hisban spring 1 Soneh	31.839096°N, 35.801110°E	*Baetis monnerati, Baetis pacis*	Slow moving freshwater with muddy and gravel bottom and vegetation (ferns and moss)
8	Hisban spring 2	31.837601°N, 35.799053°E	*Baetis monnerati, Caenis Antonina*	Shallow small creek of moderate to slow moving freshwater with muddy and gravel bottom and heavy emergent reeds and other aquatic plants
9	Hisban creek	31.8158°N, 035.7918°E	*Baetis monnerati, Caenis macrura*	Fast to moderate freshwater currents, gravel bottom with vegetation
10	W. Atun10	31.546203°N, 35.566248°E	*Cheleocloeon soldani, Nigrobaetis vuatazi, Choroterpes ortali*	Moderate to slow moving freshwater with gravel bottom in the middle and muddy substrates near the stream banks
11	W.Mujib, close to the Mujib dam	31.44488°N, 035.81635°E	*Baetis monnerati*	Slow moving freshwater with dense emergent reeds and algal mates with muddy bottom
12	W. Ibn Hammad 1 Yarout	31.282247°N, 35.691950°E	*Baetis monnerati*	Well vegetated moderate to slow moving freshwater with coarse and fine substrates
13	W. Ibn Hammad 2	31.298950°N, 35.638466°E	-	Thermal mineral spring water
14	W.Karak (Sarah creek)	31.196542°N, 35.696484°E	*Baetis monnerati, Caenis macrura*	Moderate to slow moving freshwater with gravel bottom in the middle and muddy substrates near the stream banks
15	W. Karak after WTP	31.234050°N, 35.653561°E	*Baetis monnerati*	Fast brownish running freshwater, gravel bottom
16	W. Hasa Alburbita creek	30°59'06.8°N 35°37'07.1°E	*Baetis monnerati, Caenis macrura*	Fast to moderate freshwater currents, gravel bottom,
17	W. Hasa2 Afra thermal spring	30.968974°N 35.641592	-	Thermal spring water
18	18. W. Hasa 3, Afra creek	30.969775°N, 35.640141°E	*Choroterpes (Euthraulus) ortali*	Fast to moderate warm freshwater currents with gravel bottom and algae
19	W. Hasa 4 stream mixing with Afra thermal	30.969577°N, 35.640188°E	*Choroterpes (Euthraulus) ortali , Baetis monnerati*	Fast to moderately running freshwater with stone bottom and highly vegetation
20	W. Hasa 5 Majhoul near Tafielh	30°59'06.8°N 35°37'07.1°E	*Baetis monnerati, Caenis macrura, Choroterpes (Euthraulus) ortali, Nigrobaetis vuatazi*	Fast moving freshwater, gravel bottom with dense vegetation
21	W. Hasa 6, down near the Dead Sea	31.015979°N, 35.491612°E	*Baetis monnerati*	Shallow, wide, and slow running freshwater with gravel substrates

Table 2. Composition of the water samples from studied sites (locations refer to Table 1)

Location	EC (µS/cm)	Temp	pH.	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)
1	567	19.1	8.51	3.7	1.54	0.62	0.03
2	1.920	36.6	6.9	7.2	4.7	8.719	0.46
3	882	19.7	7.1	4.01	2.35	2.47	0.08
4	2.200	18.9	7.52	6.08	5.72	10.07	0.97
5	2.380	21	8.4	5.97	6.42	10.31	0.86
6	16.120	21.8	8.02	40.01	58.2	63.11	5.51
7	630	19.9	7.54	3.25	2.05	0.93	0.07
8	743	19.2	7.04	4.315	2.12	1.01	0.09
9	795	18.2	7.44	4.69	1.88	1.13	0.08
10	2.038	17.9	6.73	5.88	2.9	10.60	0.67
11	925	17.3	7.71	3.73	2.351	2.96	0.247
12	787	21.6	7.55	4.52	2.67	1.48	0.03
13	775	45.5	6.5	2.16	1.67	4.22	0.14
14	740	21.5	8.15	4.11	2.1	1.4	0.59
15	655	21.1	8.5	5.18	3.83	4.79	0.19
16	923	22	6.92	4.53	1.75	1.19	0.10
17	558	45.5	6.87	2.35	1.47	1.58	0.06
18	440	33.2	7.03	2.35	1.47	1.58	0.06
19	618	25.5	6.8	4.8	2.47	3.72	0.14
20	660	25.6	7.44	4.69	1.88	1.13	0.08
21	823	25	8.1	5.18	3.83	4.79	0.19

Table 3. Continuation to Table 2 (locations refer to Table 1)

Location	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	NO3 (meq/l)	PO_4 (mg/l)	COD (mg/L)	BOD (mg/L)
1	3.87	0.17	0.95	0.51	0.107	10.05	5.01
2	7.13	9.34	3.31	0.08	0.21	15.8	0
3	3.98	2.97	1.58	0.32	0.23	8.74	0
4	6.53	11.9	1.54	1.24	0.33	60.09	25
5	2.98	12.01	5.62	1.46	0.26	50.83	21.63
6	5.91	58.45	89.05	5.88	0.17	27.8	15
7	4.57	0.81	0.49	0.56	0.09	1.04	0
8	4.71	0.89	0.72	0.68	0.18	1.39	0
9	3.38	0.94	0.67	0.71	1.31	12.78	0
10	3.701	7.37	8.35	0.80	0.15	6.2	33.91
11	1.57	2.86	4.39	0.15	0.31	45.2	5
12	5.13	1.27	2.11	0.17	0.11	30.6	20
13	3.12	2.85	1.73	0.01	0.63	4.79	0.02
14	3.45	2.05	1.38	50	0.11	8.2	0
15	1.57	4.77	7.26	0.12	0.01	20.19	15
16	4.09	1.32	1.06	0.71	0.22	16.79	15
17	2.18	1.96	1.38	2.18	6.5l		
18	2.18	1.96	1.38	0.08	0.21	10.5	0
19	4.13	2.03	1.25	0.1	0.51	8.3	0
20	3.38	0.94	0.669	0.71	1.31	10.2	0
21	1.57	4.766	7.259	0.116	0.01	20.19	15

Figure 2. Examples of mayfly nymphs from running water in the studied site

Baetis monnerati are found again in the same stream downstream of Tannur Dam, with a salinity of about 950 µS/cm. That indicates that *Baetis monnerati* can tolerate some salinity up to 950 µS/cm. Furthermore, this species seems to be sensitive to increasing temperature as obviously found in Wadi Hasa Afra small creek with 440 µS/cm and 33.20C warm water (site 18). These conditions affected negatively the existence of mayfly community. Here, only small population of *Choroterpes ortali* species with Naucoridae insects (maybe *Heleocoris minusculus* [22], Hydrophilidae beetles and microbes survive, while *Baetis monnerati* is not present anymore in this location. That indicate that *Choroterpes ortali* is less sensitive to warm water but it is not present in Afra water spring (site 17) with temperatures higher than 450C. In the same wadi, close to Afra creek just when the water of Afra creek mixes with Wadi Hasa water (site 19), water temperature deceased to 25.5 and suddenly life comes back to the steam

with strong occurrences of mayfly assemblages represented by the two species *Choroterpes ortali* and *Baetis monnerati*, in addition to caddisfly and flat-worms. In the fast flowing creek of Wadi Hasa (Wadi Majhoul, site 20), possessing good water quality of 660 µS/cm and 25.60C, mayfly species are more abundant and diverse (*Choroterpes ortali, Nigrobaetis vuatazi, Baetis monnerati, Caenis macrura*) (Figure 2).

In Wadi Hasa downstream area near the Dead Sea (site 21), in the slow flowing water, only *Baetis monnerati* occurred, where the water quality became poor as a result of tourism and some irrigation return flows containing biocides and fertilizers. *Nigrobaetis vuatazi* is a mayfly species in the family Baetidae. It was collected in two habitat types in different sites of Wadi Atun and Wadi Hasa with a salinity ranging from 650 µS/cm in the fast flowing, clean W. Hasa Majhoul water to 2000 µS/cm in the slow moving polluted water of Wadi Atun. Furthermore, Alhejoj et al. noted that *Nigrobaetis vuatazi* tolerates mineralized running water with high concentration of Sr 2+, reaching around 37 ppm and Br - concentration (10 ppm). Resembling of these locations showed that *Nigrobaetis vuatazi* found in Wadi Atun, 2019 and Wadi Majhoul (Wadi Hasa), can also live in mineral and polluted water and can tolerate some salinity but cannot associate high salinity with increasing temperature >350C. *Cheleocloeon soldani* also inhabit Wadi Atun slightly saline, moving, and mineralized water. Alhejoj et al. [23] recorded this species from different other locations such as Wadi Ghuweir; a small tributary to the Yarmouk River and Wadi Atun. *Cheleocloeon soldani* are found associated with *Choroterpes ortali* and *Nigrobaetis vuatazi* in Wadi Atun, showing that these species can be found in wide range of environments, in fresh to slightly salty and normal to mineralized water. In addition, this species can survive in polluted water, as is present in Wadi Atun with a BOD concentration of 33.9 mg/l. *Baetis pacis*, members of Baetidae family, was observed in Soneh spring (2013) associated with Platyhelminthes (flat worms), gastropods genera including Theodoxus and Melanopsis. This species is uncommon in Jordan and only recognized in very good water quality with narrow habitat conditions. Theodoxus and Melanopsis are absent in the other sites of the same wadi having the same environmental conditions, as they are affected by the relatively small amount of household sewage joining the stream, which indicates the highly sensitivity of the species to even slight pollution of freshwater bodies. The species *Cloeon vanharteni*, in contrast to the other species of Baetidae that occupy lotic water bodies, typically inhabits the lentic water of a small pond, very close to Karama Dam. The pond shows high occurrences of algae mats, aquatic vegetation and with a salinity of 16.120 µS/cm. That means this species is able to colonies brackish water containing relatively high nutrients contents.

Alhejoj et al. [18], registered *Cloeon gr. simile* mayflies in the same site. Mayflies of Caenidae family reported and described from Jordan consist of *Caenis macrura, Caenis antoniae*, and *Caenis parabrevip* [21, 23]. They are less common and less abundant than Baetidae species. From this study results, mayflies Caenidae tolerate pollution to a lower degree than Baetidae species, which explains the appearance of *Caenis macrura* and *Baetis monnerati* in Wadi Karak at Sarah creek site. When the treated wastewater of Karak WTP mixes with Wadi Karak stream *Caenis macrura* species is disappears and only *Baetis monnerati* survives. In addition, they are not found in Zarqa River, near to Khribet as Samara or even downstream in Abu Zighan site. In various study sites, *Caenis macrura* occur associated with *Baetis monnerati*, like in Wadi Arab, Wadi Rajib, Wadi Hisban, and Wadi Majhoul (Figure 3). That indicates good water quality ranging from clean to moderate polluted water. *Caenis macrura* appears to be more sensitive to pollution than *Baetis monnerati*, which can tolerate some degree of pollutants by domestic sewage, animal wastes, washing vegetables, picnic trash and others. It seems that this species prefers running fresh relatively good quality water. *Baetis monnerati* individuals were found associated with poor water quality in sites such as Zarqa River, Wadi Ibn Hamad (Yarout), and Wadi Mujib.

Caenis antoniae is most closely associated with clean to weakly polluted running water as present in Wadi Hisabn (site 8), where also *Baetis monnerati* and gastropods fauna (Theodoxus and Melanopsis) were found. This species seems to be more sensitive to pollution than *Caenis macrura* (Figure 3). Regarding, *Caenis parabrevip*, occur rarely in water bodies in Jordan, but it was a found associated with *Caenis antoniae* in Wadi Mujib, close to Dead Sea. Mayflies of the three discussed families are not documented to survive in thermal waters with temperatures of > 450C, for examples in Abu Hamad, Abu Dableh, Zarqa Ma'in, and Afra thermal springs.

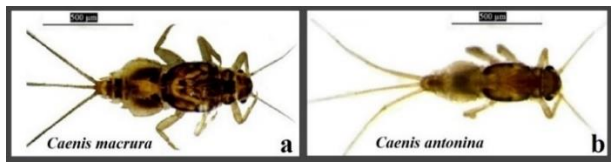

Figure 3. Two species of Caenidae, *Caenis macrura and Caenis antonina* from Wadi Hisban

4. TEST RESULTS

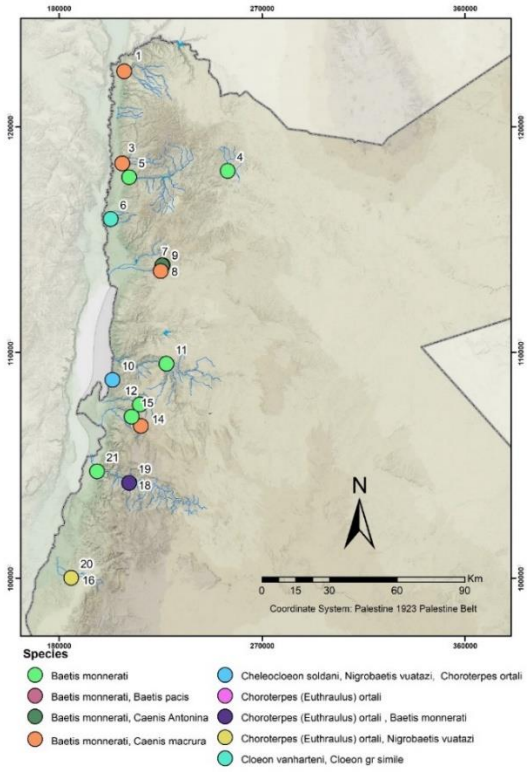

Figure 4. Aquatic mayfly assemblages in various environments from study sites (Locations refer to study sites in Table 1)

In the current work, mayfly nymphs of Baetidae, Caenidae, and Leptophlebiidae members were studied on their potential use as bio-indicators of aquatic environmental systems, mainly lotic and lontic water bodies in Jordan (Figure 4) This study found that the strong abundance and diversity of mayfly species occur in the good water quality of Wadi Hisban (site 9) and Wadi Hasa (Majhoul site20) having low salinity <800 µs/cm and temperatures of < 26°C. Mayfly nymphs show rapid response to environmental changes caused by anthropogenic stressors of domestic sewage, increased urbanization, irrigation and farming activities (e.g., biocides, fertilizers) resulting in the alteration of the chemical, and physical parameters of the hosting water bodies.

In Jordan, water pollution seems to be the most obvious threat to the survival of mayflies and other water organisms. It leads to reduced numbers of mayflies as noticed in downstream areas of Khirbet es Smara WTP on Zarqa River and Karak WTP on wadi Karak. The most widely distributed and diverse family of mayfly was Baetidae surviving under different habitats. Most sites of the study area were dominated by *Baetis monnerati*, survining in the running freshwater with stony and gravel substrate.

Our results indicate that *Baetis monnerati* can tolerate water salinities of about 1.000 µS/cm, polluted water with low oxygen content, but it is sensitive to mineral warm water. While, contents *Baetis pacis* mayflies are characterized by narrow habitat tolerance and only occur in very clean freshwater, which makes them good bioindicators for very good water quality. In addition, *Cheleocloeon soldani* are found associated with *Choroterpes ortali* and *Nigrobaetis vuatazi*, which have the ability to survive in mineral, slightly salty, and polluted environments.

We never observed Caenidae species alone but always associated with Baetidae in moving freshwater water and stony and muddy substrates. *Caenis macrura* does not inhabit heavily polluted water, but it inhabits clean to moderately polluted running freshwater. While *Caenis antoniae* is less pollution tolerant and indicates clean to weakly polluted water. *Cloeon vanharteni* was found to live in a lentic brackish small water pond with salinity of about 16.000 µS/cm (high conductivity).

The study results suggest that, Baetidae family is a more valuable macroinvertebrates group for use as biological indicator of the environmental conditions of aquatic bodies in Jordan than the other Ephemeroptera families of Caenidae and Leptophlebiidae. That is because of several reasons such as:

- It is a major component of macroinvertebrate group, it was recorded as the most abundance and diverse family of Ephemeroptera mayflies [20, 21]. Its nymphs colonized most of the habitats in both fresh and brackish water, fast or slow moving and still water.
- It is dependent on environmental conditions and is influenced by hydrological, physicochemical, and biological factors such as salinity, pollution, trace elements and water temperature.
- It is easily found and collected.
- The taxonomy of this family is well known from Ephemeroptera fauna, which was classified to species level with seven species while in the case of Caenidae, three species and Leptophlebiidae, one species [20-23]. Several researchers have focused on this mayfly family as biological indicators throughout the worlds [18, 24-26]. On other hand, our results confirmed Alhejoj et al. [23] study that mayfly nymphs are the perfect indicator candidate of the environmental conditions of Jordanian water bodies. These authors also showed that there is a clear relationship between mayfly communities and water physicochemical parameters.

Additional studies are still needed to cover more groups of the aquatic fauna in order to better understand the relationships between these groups and their environmental conditions to enable their use as bio indicators of the quality of the environmental.

Also, although some taxonomy studies worked on identification of Jordanian mayfly last ten years especially Baetidae family, but is still in progress and need more work to identify numerous unknown mayfly species which represent big challenge in case to identify them to species level in order to use them as the environmental biological indictors.

5. CONCLUSIONS

In this study, it is concluded that aquatic mayfly varies in their sensitivity and response to environmental changes including water salinity, water composition, temperature, mineral water and other physico-chemical factors.

The presence or absence of certain species of mayflies can serve as powerful indicator for environmental condition and that proved to be a fast and trustful way of indicating changes taking place in the water quality.

Baetidae mayfly are considered to be important group of aquatic invertebrates in Jordanian biomonitor system for watercourses.

Also, the study result will enable comparison with any future changes in the natural habitat expected to take place as a result of planned developments.

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