Review of Hydrobiology
www.reviewofhydrobiology.com
3,1: 27-36 (2010)

RESEARCH ARTICLE

Use of Simuliidae (Insecta, Diptera) species as indicators of aquatic habitat quality of Yeşilırmak River Basin (Turkey)

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ABSTRACT

1. In order to determine the Simuliidae fauna of Yeşilırmak River Basin and relationships between Simuliidae species and water quality, benthic macroinvertebrate samples collected between 14 and 31 July 2008.
2. Physical and chemical variables of habitats such as water temperature, pH, conductivity, dissolved oxygen, turbidity and nitrite were also given.
3. As a result of this study, 10 Simuliidae species (*Metacnephia* sp., *Simulium (E.) angustipes, Simulium (N.) costatum, Simulium (S.) argenteostriatum, Simulium (S.) bezzii, Simulium (S.) ornatum, Simulium (S.) trifasciatum, Simulium (W.) balcanicum, Simulium (W.) lineatum, Simulium (W.) pseudequinum*) were determined from 12 collecting sites. *Simulium (N.) costatum* and *Simulium (S.) trifasciatum* were recorded from Yeşilırmak River Basin for the first time.
4. Ecological quality of collecting sites was classified according to the results of Biological Monitoring Working Party (BMWP) score and Belgian Biotic Index (BBI).
5. Yeşilırmak River has been affected by various human activities (industries, urban sewage, organic effluent, dams, hydroelectric power plants). Relationships between these environmental variables and Simuliidae species were assessed.
6. Simuliidae species were indicators of water and habitat quality of Yeşilırmak River Basin because of distribution of indicator Simuliidae species concordant with water quality.

KEY WORDS: Blackflies, BMWP, BBI, dam, habitat degradation, indicator, physico-chemical variables, Simuliidae, Turkey, water quality, Yeşilırmak River Basin.

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Simuliidae (Insecta, Diptera) türlerinin Yeşilırmak Nehri Havzası (Türkiye)'nın sucul habitat kalitesini belirlemede indikatör olarak kullanılmaları

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ÖZ

1. Yeşilırmak Nehir Havzası'nın Simuliidae faunasını ve Simuliidae türlerinin su kalitesi ile ilişkilerini belirlemek amacıyla, 14-31 Temmuz 2008 tarihleri arasında bentik büyük omurgasız örnekleri toplanmıştır.
2. Habitatların su sıcaklığı, pH, iletkenlik, çözünmüş oksijen, bulanıklık ve nitrit gibi fiziksel ve kimyasal değişkenleri verilmiştir.
3. Çalışma sonucunda, 12 istasyonda, 10 Simuliidae türü (*Metacnephia* sp., *Simulium (E.) angustipes, Simulium (N.) costatum, Simulium (S.) argenteostriatum, Simulium (S.) bezzii, Simulium (S.) ornatum, Simulium (S.) trifasciatum, Simulium (W.) balcanicum, Simulium (W.) lineatum, Simulium (W.) pseudequinum*) saptanmıştır. *Simulium (N.) costatum* ve *Simulium (S.) trifasciatum* Yeşilırmak Nehri Havzası'ndan ilk kez kaydedilmiştir.
4. İstasyonların ekolojik kalite sınıfları, Biyolojik İzleme Çalışma Grubu Skor Sistemi (BMWP) ve Belçika Biyotik İndeksi (BBI) sonuçlarına göre belirlenmiştir.
5. Yeşilırmak Nehri, çeşitli insan aktivitelerinden (sanayi, şehir kanalizasyonları, organik atıklar, barajlar, hidroelektrik santralleri) etkilenmektedir. Bu çevresel değişkenler ile Simuliidae türleri arasındaki ilişki değerlendirilmiştir.
6. Simuliidae türlerinin, Yeşilırmak Nehri'ndeki dağılımı su ve habitat kalitesi ile örtüşmektedir. Bu nedenle Simuliidae türleri, Yeşilırmak Nehri'nin su ve habitat kalitesini belirlemede ve izlemede biyoindikatör olarak kullanılabilir.

ANAHTAR KELİMELER: Baraj, BMWP, BBI, fiziko-kimyasal değişkenler, habitat bozulması, indikatör, kara sinekler, Simuliidae, su kalitesi, Türkiye, Yeşilırmak Nehri Havzası.

INTRODUCTION

Communities of preimaginal Simuliidae are important component of running water habitats. Many rivers and streams are impacted by organic and industrial pollution and morphological degradation in Turkey. The monitoring of ecological quality of aquatic ecosystems is necessary for their protection. The reliable monitoring methods must primarily comprise biotic indicators. Benthic macroinvertebrates are the most suitable organisms for monitoring of habitat quality of aquatic ecosystems (Hellawel 1986, Rosenberg and Resh 1983). The insufficent taxonomical and ecological knowledge prevent reliable usage of benthic macroinvertebrates in biomonitoring activities in Turkey. Various taxonomical groups (e.g. Ephemeroptera, Odonata, Plecoptera, Trichoptera, Simuliidae, Chironomidae) must be studied extensively in species level.

The purposes of the research were to determine the Simuliidae fauna of Yeşilırmak River Basin, species distribution in relation to aquatic habitat quality and whether distribution of indicator Simuliidae species concordant with water quality.

METHODS AND MATERIALS

Site description

Yeşilırmak River is an important running water in the Northeastern Turkey. Its basin covers an area of 5% of Turkey. The drainage basin of Yeşilırmak River covers an area of 36.114 km^2 with its 519 km length. The river has been impacted by various human activities. The habitat quality of river was affected by organic effluent, toxic substances and morphological degredation.

Important pollution sources of the stream are industries, sewage from urban areas and agricultural runoff. There are dams, regulators, irrigation projects and hydroelectric power plants in the Yeşilırmak River Basin.

Collecting sites are characterized by large-sized (>1000-10000 km^2) silicious and calcareous with altitudes ranging from 247-1580 m according to System A of the EU Water Framework Directive **(**WFD).

Physical and chemical analyses

Water temperature, pH, conductivity (YSI multiprobe system) and dissolved oxygen (YSI 550 oxygen meter) were measured *in-situ* with a water analyser. Water samples were preserved in cooling conditions (4 ºC), were filtered upon arrival in the laboratory, and were analyzed (DR/890 Datalogging Colorimeter) for nitrite. The physical and chemical properties of sites Yeşilırmak-1, 2 and 3 were not given.

Benthic macroinvertebrate sampling and identification

Macroinvertebrate samples were taken at each site during the field surveys conducted in summer (between 14 and 31 July 2008). Fifteen-minute kick-samples were taken using standard pond net from each type of habitat at each site. Simuliidae species were collected also by hand. Samples were preserved in 80% ethanol. Leica MZ75 binocular stereo microscope and Olympos CX21FS1 binocular microscobe were used for identifications. Species were identified according to Rubtsov 1990 and Lechthaler and Car 2005.

Data analysis

Ecological quality of collecting sites was classified according to the results of BMWP (Biological Monitoring Working Party) and BBI (Belgian Biotic index). The BBI score of site 12 could not be calculated due to inadequate number of taxa.

RESULTS

Environmental features of the streams

Physical variables

Stream order ranged from 1 to 3 and elevations of the sites were between 280 m and 1580 m. Substratum structure was similar at all sites, and consisted mainly of rocks, boulders, cobbles, pebbles and sands. Water temperature values were between 18.94 °C and 25.79 °C. Turbidity values were high at some sites: 1-103 FAU.

Chemical variables

Conductivity values recorded were between 251 µS/cm and 775 µS/cm. The dissolved oxygen values recorded were between 3.11 mg/l and 8.83 mg/l. The streams were alkaline with pH ranging from 7.87 to 8.72. Nitrite concentrations were generally high between 0.021 mg/l and 0.29 mg/l.

According to nitrite concentrations all collecting sites were impacted by organic pollution and their water quality classes were between II and IV. The collecting sites Yeşilırmak 10, Yeşilırmak 11 and Yeşilırmak 12 were also physically disturbed because of impacts of dams.

Ecological quality criteria

While BMWP score values were between 11 and 82, BBI values were between 6 and 8.

Collecting sites and dates

Yeşilırmak 1: Amasya, Yeşilırmak River, 407m, 14. 7. 2008, 40° 34' 21.4'' N/ 35° 46' 31.3'' E

Yeşilırmak 2: Amasya: Amasya- Borabay Road, Yeşilırmak River, 340m, 15. 7. 2008, 40° 41' 52.5'' N/35° 56' 23.1'' E

Yeşilırmak 3: Amasya: Amasya- Borabay Road, Yeşilırmak River, 280m, 15. 7. 2008, 40° 45' 06.4'' N/36° 04' 20.7'' E

Yeşilırmak 4 (Kelkit 1): Gümüşhane: Kelkit: Aksu Village, Kelkit-Şiran Road, Kelkit Stream, 1430m, 24.07.2008, 40° 08' 00.4'' N/ 39° 24' 08.5'' E

Yeşilırmak 5 (Kelkit 2): Gümüşhane: Şiran: Seydibaba Village, a tributary of Kelkit Stream, 1310m, 24.07.2008, 40° 09' 34.0'' N; 39° 01' 53.8'' E

Yeşilırmak 7 (Kelkit 4): Gümüşhane: Şiran: Tomara Waterfall, Kelkit Stream, 1260m, 24.07.2008, 40° 05' 27.2'' N; 39° 02' 50.6'' E

Yeşilırmak 8 (Kelkit 5): Giresun: 25 km to Şebinkarahisar: Balcana Village and Bridge, a tributary of Kelkit Stream, 1280m, 24.07.2008, 40° 20' 40.9'' N; 38° 36' 36.9'' E

Yeşilırmak 10 (Kelkit 7): Sivas: 10 km to Koyulhisar, Kelkit Stream after Çamlıgöze Dam, 730m, 25.07.2008, 40° 15' 37.0'' N; 37° 54' 08.3'' E

Yeşilırmak 11 (Kelkit 8): Sivas: Koyulhisar: Yukarıkale Village, Kelkit Stream, 653 m 25.07.2008, 40° 16' 36.4'' N; 37° 52' 10.3'' E

Yeşilırmak 12 (Kelkit 9): Tokat: Reşadiye, Kelkit Stream, 1580m, 25.07.2008, 40° 22' 28.9'' N; 37° 22' 59.5'' E

DISCUSSION

Ten species of Simuliidae were recorded from Yeşilırmak River Basin (Table 1). One of them was identified in genus level. *Metacnephia* sp. was distinct from *Metacnephia subalpina* and *Metacnephia lyra* which were previously recorded species of this genus from Turkey (Kazancı and Ertunç 2008). First record of *Metacnephia subalpina* was given from Ankara in central Anatolia by Crosskey (1988). *Metacnephia lyra* was reported as a new record for Turkey from Büyük Menderes River Basin in Southeastern Anatolia (Kazancı and Ertunç 2008). *Simulium (Nevermannia) costatum* and *Simulium (Simulium) trifasciatum* were recorded from Yeşilırmak Basin for the first time.

BMWP and BBI were used for ecological quality assessment of collecting sites. These macroinvertebrate metrics have been intensively applied by various researchers in Turkey (Kazancı and Türkmen 2010). The BMWP score is calculated by adding the score (1 being highly tolerant, 10 highly sensitive) of each family. Therefore total BMWP score is related to taxon richness. The lower cumulative score is lower BMWP index value indicated polluted sites (Mandaville 2002). The BBI ranges from 0 (very heavily

polluted) to 10 (good water quality). According to De Pauw and Vanhooren (1983), 10-9 is class I (good water quality), 8-7 is class II (slightly polluted water), 6-5 is class III (moderately polluted water), 4-3 is class IV (heavily polluted water), 2-0 is class V (very heavily polluted water).

Table 1. Species list of Simuliidae, number of larvae and pupae, and their collecting sites.

Collecting sites	Species	Larvae	Pupae
Yeşilırmak-1	*Simulium (Wilhelmia) balcanicum* Enderlein, 1924	46	40
	Simulium (Wilhelmia) pseudequinum Seguy, 1921	11	5
Yeşilırmak-2	*Simulium (Wilhelmia) balcanicum*	58	3
Yeşilırmak-3	*Simulium (Wilhelmia) balcanicum*	24	7
	Simulium (Wilhelmia) pseudequinum	3	-
Yeşilırmak-4	*Simulium (Wilhelmia) balcanicum*	5	-
	Simulium (Wilhelmia) pseudequinum	2	-
Yeşilırmak-5	*Simulium (Eusimulium) angustipes* Edwards, 1915	10	-
	Simulium (Simulium) bezzii Corti, 1914	150	25
	Simulium (Wilhelmia) balcanicum	15	9
	Simulium (Wilhelmia) pseudequinum	35	68
Yeşilırmak-7	*Simulium (Wilhelmia) lineatum* Meigen, 1804	8	-
Yeşilırmak-8	*Metacnephia* sp.	-	1
	Simulium (Eusimulium) angustipes	2	-
	Simulium (Nevermannia) costatum Friederichs, 1920	-	1
	Simulium (Simulium) argenteostriatum Strobl, 1898	1	-
	Simulium (Simulium) bezzii	37	3
	Simulium (Simulium) ornatum Meigen, 1818	-	1
	Simulium (Simulium) trifasciatum Curtis, 1839	1	-
	Simulium (Wilhelmia) balcanicum	48	13
	Simulium (Wilhelmia) pseudequinum	17	2
Yeşilırmak-10	*Simulium (Simulium) bezzii*	2	-
Yeşilırmak-11	*Simulium (Simulium) bezzii*	-	1
	Simulium (Wilhelmia) balcanicum	-	2
	Simulium (Wilhelmia) pseudequinum	1	-
Yeşilırmak-12	*Simulium (Simulium) bezzii*	2	-

The low BMWP score values were recorded as 11, 26, 40 and 61 in collecting sites YI-12, YI-4, YI-10 and YI-11 respectively. High concentrations of nitrite nitrogen were noted at site 4. The main reason of low BMWP score values was dam effects at sites YI-11, YI-12 and YI-10 (values of nitrite nitrogen were not high, between 0.01 and 0.02 mg/l).

The BBI scores were between 6 and 8. According to ecological water quality criteria the water quality of sites YI-5, YI-7 and YI-8 (BBI scores were 7, 7 and 8 respectively) were in class II (slightly polluted) while the water quality of sites YI-4, YI-10 and YI-11 (BBI scores were 6 at these sites) were in class III (moderately polluted). The BMWP and BBI scores were high at site YI-5 in spite of high value of nitrite nitrogen (water quality class IV with 0.09 mg/l nitrite nitrogen). The reason of the high value of nitrite nitrogen was low amount of water in stream because of summer period droughtness.

Metacnephia sp. was recorded from site YI-8 where was slightly polluted (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). Saprobic level of species belong to this genus is unknown but collecting sites of this species were oligosaprobic environment (water quality class I) in Southern Spain (Gallardo-Mayenco and Toja 2002).

Simulium (Eusimulium) angustipes was recorded from polluted site YI-5 (water quality class IV) according to nitrite nitrogen value (0.09 mg/l) and was recorded from slightly polluted site YI-8 (water quality class II with 0.01 mg/l nitrite nitrogen). The ecological qualities of these two sites were high according to BMWP and BBI scores. This species prefers mainly betamesosaprobic environments but it occurs also in oligosaprobic and in alphamesosaprobic environments (Car 1995).

Simulium (Nevermannia) costatum was recorded from slightly polluted site YI-8 (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). This species prefers mainly betamesosaprobic environment but it occurs also in oligosaprobic environment (Car 1995).

Simulium (Simulium) argenteostriatum was recorded from site YI-8 where was slightly polluted (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). This species prefers mainly oligosaprobic environment but it occurs also xenosaprobic environment (Car 1995).

Simulium (Simulium) bezzii was recorded from sites YI-5, YI-8, YI-10, YI-11 and YI-12. Sites YI-5 and YI-8 were slightly polluted (water quality class II), YI-10 and YI-11 (nitrite nitrogen value was 0.02 mg/l) were moderately polluted (water quality class III)

according to BMWP and BBI scores. Water quality of site YI-12 was low and BMWP score value was 11. BBI score can not calculated in this site due to inadequate number of taxa. This species prefers mainly oligosaprobic and betamesosaprobic environments (CSN 1998). *Simulium (Simulium) bezzii* was found all sites (YI-10, YI-11 and YI-12) impacted by dams. According to results of this study *Simulium (Simulium) bezzii* resistant to physical habitat degradation.

Simulium (Simulium) ornatum was recorded from site YI-8 where was slightly polluted (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). This species prefers mainly alphamesosaprobic and betamesosaprobic environments but it occurs also in oligosaprobic environment (Car 1995). Ertunç et al. (2008) recorded this species from betamesosaprobic environment from Yedigöller National Park. Lautenschlager and Kiel (2005) reported that *Simulium (Simulium) ornatum* larvae are more resistant to hydrochemical degradation of running waters.

Simulium (Simulium) trifasciatum was recorded from site YI-8 where was slightly polluted (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). This species prefers mainly oligosaprobic and betamesosaprobic environments (Car 1995). Ertunç et al. (2008) reported this species from betamesosaprobic environment from Yedigöller National Park.

Simulium (Wilhelmia) balcanicum was recorded from sites YI-1, YI-2, YI-3, YI-4, YI-5, YI-8 and YI-11. Sites YI-5 and YI-8 were slightly polluted (water quality class II) while YI-4 (nitrite nitrogen value was 0.05 mg/l) and YI-11 (nitrite nitrogen value was 0.02 mg/l) were moderately polluted (water quality class III) according to BMWP, BBI scores. The nitrite nitrogen value was 0.04 mg/l at site YI-4 and was 0.02 mg/l at site YI-11. This species prefers mainly betamesosaprobic environment but it occurs also alphamesosaprobic environment (Car 1995).

Simulium (Wilhelmia) lineatum was recorded from site YI-7 where was slightly polluted (water quality class II) according to BMWP, BBI scores and nitrite nitrogen value (0.01 mg/l). This species prefers mainly betamesosaprobic environment but it occurs also in oligosaprobic and in alphamesosaprobic environment (Sporka 2003). Ertunç et al. (2008) found this species in betamesosaprobic environment in Yedigöller National Park.

Simulium (Wilhelmia) pseudequinum was recorded from sites YI-1, YI-3, YI-4, YI-5, YI-8 and YI-11. Sites YI-5 (water quality class IV with 0.09 mg/l nitrite nitrogen) and YI-8 were slightly polluted (water quality class II with 0.01 mg/l nitrite nitrogen) while YI-4 (nitrite nitrogen value was 0.05 mg/l) and YI-11 (nitrite nitrogen value was 0.02 mg/l) were moderately polluted (water quality class III) according to BMWP, BBI scores

and nitrite nitrogen value. This species prefers mainly betamesosaprobic environment but it occurs also in alphamesosaprobic environment (Sporka 2003). Kazancı (2006) reported that *Simulium (Wilhelmia) pseudequinum* was positively correlated with turbidity and temperature increase. Ertunç et al. (2008) found this species in betamesosaprobic environment in Yedigöller National Park.

Simulium (Wilhelmia) balcanicum (YI-11), *Simulium (Simulium) bezzii* (YI-10, YI-11 and YI-12) and *Simulium (Wilhelmia) pseudequinum* (YI-11) distributed at sites below the dams but their abundances were very low (Table. 1). *Simulium (Simulium) balcanicum* and *Simulium (Wilhelmia) pseudequinum* can tolerate increasing turbidity and temperature (Kazancı 2006). These variables were seriously affected by dams in running water habitats. Flow regulations had negative effects on the abundance and species richness of Simuliidae. Species abundance and richness significantly decreased at sites impacted by dams. Responses of river ecosystems to dams are complex and varied. Some macroinvertebrate species are eliminated or reduced in abundance because of changes of physical, chemical and biological nature of downstream region (Chester and Norris 2006). Kazancı (2006) reported that *Simulium (Wilhelmia) balcanicum* was positively correlated with increasing temperature and turbidity. In collecting sites below dam, alteration of these variables depend on impacts of dam.

According to the results of this study physical and chemical properties of habitats may have impacted the species composition of Simuliidae species. Community structures of Simuliidae were negatively affected by flow alterations due to dam impacts. Simuliidae species were indicators of water and habitat quality of Yeşilırmak River Basin because of saprobic properties of distributed indicator Simuliidae species concordant with water and habitat quality.

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