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ORIGINAL PAPER

Evaluation of Plecoptera (Insecta) community composition using multivariate technics in a biodiversity hotspot

N. Kazanci[1] · G. Turkmen[1] · P. Ekingen[1] · O. Basoren[1]

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Abstract Eastern Black Sea Region of Turkey is a sub-ecoregion of the Caucasus Ecoregion, and its Plecoptera fauna is similar to fauna of Caucasus with unique endemic species of the region. The Caucasus Ecoregion is one of the "WWF Global 200 Ecoregions," and it is also included in the list of top 25 hotspots in the World. Running water ecosystems of Eastern Black Sea sub-ecoregion are the most sensitive to land use change and global climate change. High-altitude aquatic ecosystems are more strongly threatened by global climate change in the region. Plecoptera constitute the most important part of the biodiversity of running waters in the region. Among the benthic macroinvertebrate taxa, Plecoptera is the best indicator of ecological conditions of running waters. The influence of environmental variables on the distribution of twenty Plecoptera species in running water ecosystems (headwaters, crenon, epirhithron, metarhithron) was assessed using canonical correspondence analysis. Sampling was carried out in 2009 and 2011. Eleven end groups were generated from the TWINSPAN analysis. *Isoperla rhododendri*, *Isoperla grammatica*, *Protonemura bifida*, *Protonemura eumontana* and *Perla caucasica* were closely related to pH, dissolved oxygen and riparian vegetation. *Brachyptera transcaucasica transcaucasica*, *Nemoura martynovia*, *Nemoura taurica* and *Protonemura eumontana* were related to Mg and Cu. The results show that the Plecoptera assemblage composition was affected by DO, pH, EC, temperature, nitrite, Ca, Mg, Fe, Cu, Zn, Al, riparian vegetation, altitude and stream width.

Keywords CCA · Caucasus · Eastern Black Sea sub-ecoregion · Headwater · Stream · TWINSPAN

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✉ N. Kazanci
nilgunkazanci@gmail.com

[1] Department of Biology, Faculty of Science, Hacettepe University, Ankara, Turkey

Introduction

Freshwater ecosystems are used in following categories through human history (Juuti et al. 2007): (1) vital needs, (2) agriculture and farming, (3) industrial use, (4) transportation and (5) aesthetic and cultural use.

Freshwater resources are deteriorating due to high demographic growth and their use without conservation planning in many parts of the world. The essential part of management plans of river basins is biological assessment and monitoring of water quality. The various methods have been used for the biological assessment of water quality of running waters from the beginning of the twenty century.

The European Water Framework Directive (WFD) (Council of European Countries 2000) uses the components of fauna and flora of aquatic ecosystems as Biological Quality Elements (BQE) for determination of ecological status. BQE are the basic elements for water quality, while the hydromorphological and physicochemical characteristics are used as supportive variables.

Plecoptera has an important position in the methods of biological assessment of water quality evaluation in running waters. Because they are indicators of xenosaprobic and oligosaprobic habitats within the saprobic system and their use in the ecoregional biomonitoring is mandatory. According to Darilmaz et al. (2016), Turkish Plecoptera fauna contains 117 taxa belonging to 24 genera and 7 families. One of the difficulties in preparation of the

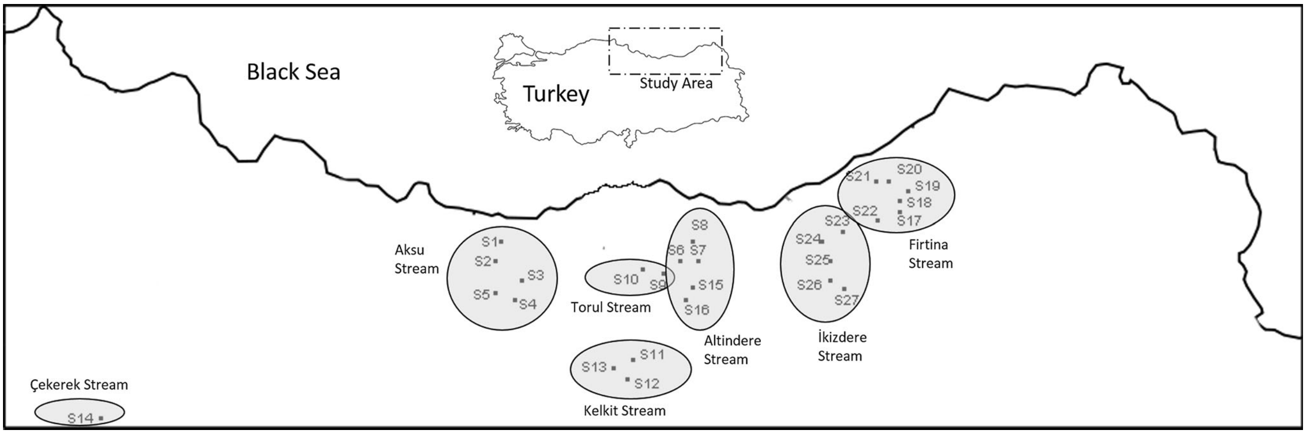

Fig. 1 Study area and sampling sites

ecoregional multimetric indices including Plecoptera species is the lack of information of their distribution and ecology (Kazancı 2008).

Various water quality variables of running waters influence the distribution of Plecoptera species. Determination of the relationships between Plecoptera species and environmental variables is compulsory for their indicative use of habitat quality.

The goal of this research was to evaluate the influence of environmental variables on the distribution of Plecoptera species in running water ecosystems of Eastern Black Sea sub-ecoregion of Caucasus ecoregion.

Materials and methods

Eastern Black Sea Region of Turkey was selected as study area (Fig. 1). In this area, there are many undisturbed freshwater habitats and unpolluted streams, which are mainly preferred by plecopteran species. This area is also important because of being a part of Caucasus Biodiversity Hotspot.

Sampling was carried out in 27 sampling sites at the beginning of June 2009 and at the beginning of July 2011. Samples were collected by sweeping adults from riparian vegetation. Dissolved oxygen (YSI 550 oxygen meter), temperature, pH and conductivity (YSI multiprobe system) were measured in the field (Fig. 2). Calcium and magnesium hardness, NO_2–N, Zn, Al, Fe^{2+}, Cu (DR/890 data logging colorimeter) were measured according to HACH (2005) (Figs. 3, 4). Leica MZ75 binocular stereo microscope was used for identifications. Zhiltzova (2003), Zwick (1971), Teslenko and Zhiltzova (2009) were mainly used for identifications.

Certain geological characteristics which are required by WFD for System A and System B classifications and certain other necessary physical characteristics of sampling sites were given in Table 1.

The relationships between 20 Plecoptera species and environmental variables were investigated by canonical correspondence analysis (CCA, Fig. 5) (ter Braak 1987; Jager and Looman 1995; Jongman et al. 1995; Lepš and Šmilauer 1999). Data sets were classified by two-way indicator species analysis (TWINSPAN, Fig. 6) (Hill 1979; Lepš and Šmilauer 1999).

Results and discussion

Values of physicochemical variables, such as dissolved oxygen, temperature, pH, electrical conductivity, concentration of NO_2–N and concentration of heavy metals, Zn, Al, Fe^{2+}, Cu, Calcium and magnesium hardness, were shown in Figs. 2, 3 and 4.

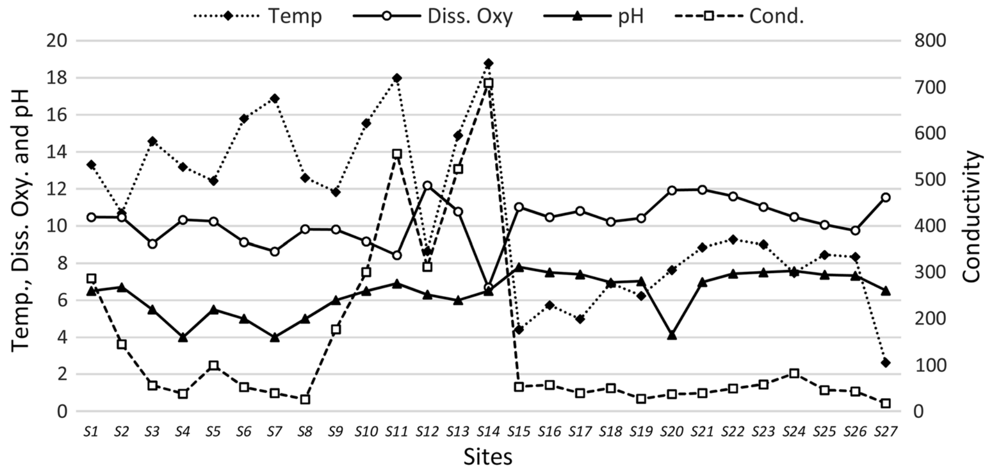

Fig. 2 Values of temperature (°C), dissolved oxygen (mg/L), pH and electrical conductivity (µS/cm)

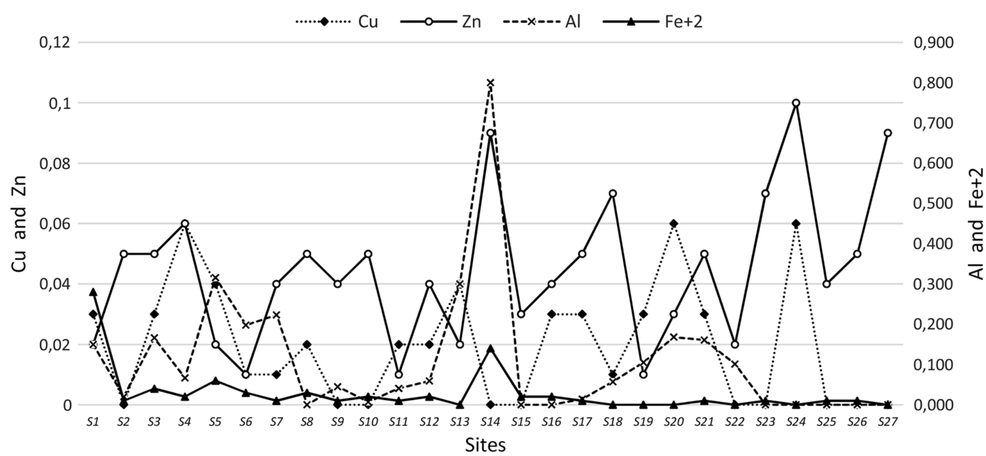

Fig. 3 Concentrations of Cu (mg/L), Zn (mg/L), Al (mg/L) and Fe^{2+} (mg/L)

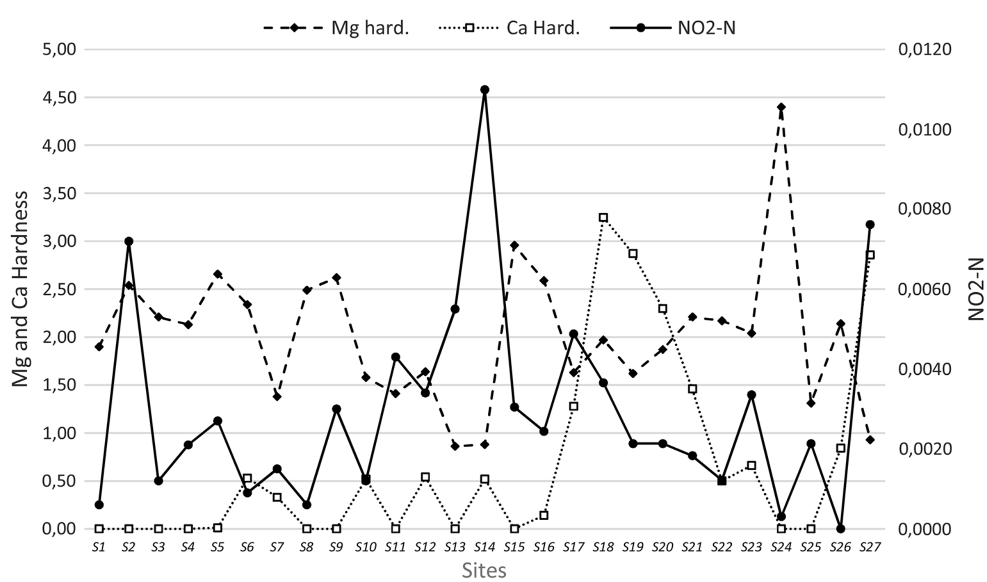

Fig. 4 Concentrations of NO_2–N (mg/L), Mg and Ca hardness (mg/L)

Table 1 System A and system B classification of sampling sites according to WFD and certain other physical characteristics

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Altitude	Mid-altitude	Mid-altitude	High	High	High	High	High	High	High
(System A)	(200–800 m)	(200–800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)
Altitude (System B)	557 m	607 m	1867 m	1542 m	1582 m	1944 m	1900 m	1573 m	1712 m
Catchment area	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
(System A)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)
Ecoregion	Y	Y	Y	Y	Y	Y	Y	Y	Y
Latitude (System B)	40°41′01.08″N	40°40′49.01″N	40°34′07″N	40°32′22″N	40°32′19″N	40°37′21.55″N	40°38′28.03″N	40°39′52.73″N	40°39′41.40″N
Longitude (System B)	38°26′29.71″E	38°26′41″E	38°28′67″E	38°24′06″E	38°21′35″E	39°35′37.67″E	39°40′48.16″E	39°40′16.73″E	39°24′50.23″E
Geology (System A)	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous
Substratum	50% Rock	30% Stone	10% Rock	70% Rock	5% Rock	75% Rock	10% Rock	30% Rock	5% Rock
	30% Stone	60% Gravel	45% Stone	25% Stone	50% Stone	15% Stone	35% Stone	30% Stone	50% Stone
	5% Gravel	10% Sand	40% Gravel	5% Gravel	30% Gravel	5% Gravel	35% Gravel	30% Gravel	30% Gravel
	15% Sand		5% Sand		15% Sand		20% Sand	10% Sand	15% Sand
Riparian Vegetation	100%	100%	60%	80%	100%	10%	50%	100%	90%
Stream zone	Epirhithron	Epirhithron	Epirhithron	Epirhithron	Hypocrenon	Hypocrenon	Hypocrenon	Hypocrenon	Hypocrenon
Stream width in dry period	2 m	0.7 m	2 m	5 m	0.5 m	0.5 m	0.3 m	0.5 m	0.5 m
Stream width in wet period	2.5 m	1.5 m	12 m	5.5 m	1 m	1 m	0.3 m	0.5 m	1 m

	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19
Altitude	High	High	High	High	Mid-altitude	High	High	High	High	High
(System A)	(>800 m)	(>800 m)	(>800 m)	(>800 m)	(200–800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)
Altitude (System B)	1301 m	1234 m	1230 m	1236 m	792 m	2435 m	2394 m	2307	2252	2018
Catchment area	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
(System A)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)
Ecoregion	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Latitude (System B)	40°38′56.96″N	40°05′26.30″N	40°05′27.38″N	40°05′28.33″N	40°03′47.97″N	40°36′20.9″N	40°36′06.7″N	40°52′39.79″N	40°53′06.40″N	40°54′21.55″N
Longitude (System B)	39°20′06.55″E	39°02′ 46.83″E	39°02′ 44.83″E	39°02′ 41.81″E	35°33′22.72″E	39°38′48.8″E	39°38′42.8″E	41°07′50.92″E	41°07′53.29″E	41°08′19.60″E
Geology (System A)	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous
Substratum	5% Rock	35% Stone	35% Stone	35% Stone	10% Stone	10% Rock	20% Rock	50% Rock	50% Rock	20% Rock
	50% Stone	50% Gravel	50% Gravel	50% Gravel	40% Gravel	45% Stone	35% Stone	30% Stone	25% Stone	50% Stone
	30% Gravel	15% Sand	15% Sand	15% Sand	10% Sand	45% Gravel	35% Gravel	15% Gravel	25% Gravel	25% Gravel
	15% Sand				40% Silt		10% Sand	5% Sand		5% Sand
Riparian Vegetation	90%	20%	30%	30%	35%	70%	100%	100%	100%	100%
Stream zone	Hypocrenon	Epirhithron	Epirhithron	Epirhithron	Epipotamon	Hypocrenon	Hypocrenon	Epirhithron	Epirhithron	Hypocrenon
Stream width in dry period	0.3 m	0.5 m	0.5 m	0.5 m	15 m	0.2 m	0.4 m	5 m	1.5 m	0.5 m
Stream width in wet period	2 m	2.5 m	1.5 m	2.5 m	35 m	0.4 m	0.6 m	5 m	2 m	1 m

Table 1 continued

	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27
Altitude	High	Mid-altitude	Mid-altitude	Mid-altitude	High	High	High	High
(System A)	(>800 m)	(200–800 m)	(200–800 m)	(200–800 m)	(>800 m)	(>800 m)	(>800 m)	(>800 m)
Altitude (System B)	974 m	568 m	507 m	560 m	2095 m	2092	2293	2570
Catchment area	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
(System A)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)	(100–1000 km^2)
Ecoregion	Y	Y	Y	Y	Y	Y	Y	Y
Latitude (System B)	40°58′00.59″N	41°01′32″N	40°59′00.64″N	40°42′48″N	40°35′59.42″N	40°35′37.61″N	40°34′15.52″N	40°32′25.33″N
Longitude (System B)	41°04′46.64″E	41°02′48″E	40°57′49.37″E	40°37′28.42″E	40°31′23.15″E	40°31′02.28″E	40°30′34.72″E	40°30′02.91″E
Geology (System A)	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous	Siliceous
Substratum	40% Rock	40% Rock	50% Rock	50% Rock	35% Rock	40% Rock	40% Rock	40% Rock
	35% Stone	30% Stone	30% Stone	30% Stone	35% Stone	40% Stone	30% Stone	30% Stone
	25% Gravel	20% Gravel	15% Gravel	15% Gravel	30% Gravel	15% Gravel	25% Gravel	25% Gravel
		10% Sand	5% Sand	5% Sand	5% Sand	5% Sand	5% Sand	5% Sand
Riparian Vegetation	90%	100%	80%	80%	100%	100%	90%	70%
Stream zone	Epirhithron	Metarhithron	Metarhithron	Hypocrenon	Metapotamon	Epirhithron	Epirhithron	Hypocrenon
Stream width in dry period	12 m	8 m	10 m	6 m	1 m	5 m	3.5 m	0.7 m
Stream width in wet period	15 m	11 m	14 m	10 m	3 m	6 m	6 m	1 m

CCA

Quadrant A

P. caucasica, *P. pallida*, *I. bithynica*, *P. eumontana*, *P. bifida* and *I. rhododendri* were related to dissolved oxygen and pH in Quadrant A, but *I. rhododendri* was also related closely to Ca hardness (Fig. 5). *P. caucasica* is a widespread species and was recorded from Ankara, Artvin, Balıkesir, Eskişehir, Muğla, Antalya, Artvin (Kazancı 1994); Ankara, Bayburt, Bolu, Giresun, Rize (Kazancı 2012, 2013). Cherchesova et al. (2012) recorded *P. caucasica* from polluted sites in Kabarda-Balkarian Republici in the Central Caucasus. According to this study, *P. caucasica* is able to live in extremely polluted running waters. Khazeeva (2010) reported *P. caucasica* from Urukh River Basin (Northern Slopes of the Central Caucasus) which is slightly affected by pollution. *P. caucasica* was recorded from unpolluted upstream region and slightly polluted downstream region. In this study, *P. caucasica* was recorded from Site 20. The water quality of this collecting site was high with high concentration of dissolved oxygen (11.92 mg/L) and low concentration of nitrate and nitrite (0.067 and 0.002 mg/L, respectively). Kazancı and Dügel (2010) stated that *P. caucasica* was related to dissolved oxygen, cadmium and pH using CCA from low-order Mediterranean streams in the Köyceğiz-Dalyan Nature Reserve which is an important wetland area in Eastern Mediterranean Region. In this study, *P. caucasica* was also closely related to dissolved oxygen in CCA diagram. The environmental preferences of *P. bifida* are unknown, but *P. bifida* closely related to pH and dissolved oxygen in CCA diagram. According to Cherchesova et al. (2012), *Perla pallida* is a common species in Kabarda-Balkarian Republici in the Central Caucasus. They found this species in spring rivers in the foothills (450–650 m above sea level). *P. pallida* prefers xenosaprobic and oligosaprobic environments mainly, but it was also found in beta-mesosaprobic environments (CSN 75 (7716) 1998; Sporka 2003). In this study, *P. pallida* was recorded in metarhithron between 507 and 568 m. Eucrenon, hypocrenon, epirhithron and metarhithron are stream zonation preference of this species (Graf et al. 2009, 2016). Girgin et al. (2010) reported two *Perla* species were related to pH from epirhithral zone of an urban stream. Cherchesova et al. (2012) recorded *I. bithynica* from polluted and unpolluted running waters. Khazeeva (2010) reported *I. bithynica* from unpolluted upstream region of Urukh River Basin which is slightly affected by pollution. In

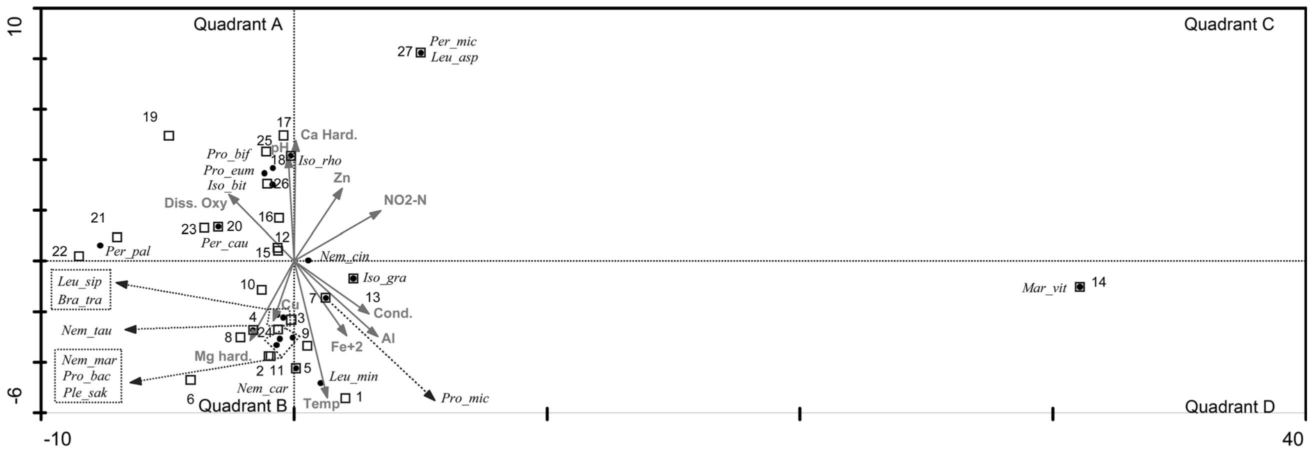

Fig. 5 CCA diagram with environmental variables

Leu_min	*Leuctra minuta minuta*	Zhiltzova, 1960	*Pro_mic*	*Protonemura microstyla*	Martynov, 1928
Leu_asp	*Leuctra aspoeckorum*	Theischinger, 1976	*Bra_tra*	*Brachyptera transcaucasica transcaucasica*	Zhiltzova, 1956
Leu_sip	*Leuctra sipahilerae*	Vinçon and Sivec, 2001	*Ple_sak*	*Plesioperla sakartvella*	(Zhiltzova, 1956)
Nem_mar	*Nemoura martynovia*	Claassen, 1936	*Iso_gra*	*Isoperla grammatica*	(Poda, 1761)
Nem_tau	*Nemoura taurica*	Zhiltzova, 1967	*Iso_rho*	*Isoperla rhododendri*	Zhiltzova, 1956
Nem_car	*Nemoura carpathica*	Illies, 1963	*Iso_bit*	*Isoperla bithynica*	(Kempny, 1908)
Nem_cin	*Nemoura cinerea turcica*	Zwick, 1972	*Mar_vit*	*Marthamea vitripennis*	(Burmeister, 1839)
Pro_bac	*Protonemura bacurianica*	Zhiltzova, 1957	*Per_mic*	*Perlodes microcephalus*	(Pictet, 1833)
Pro_bif	*Protonemura bifida*	Martynov, 1928	*Per_cau*	*Perla caucasica*	Guérin-Méneville, 1838
Pro_eum	*Protonemura eumontana*	Zhiltzova, 1957	*Per_pal*	*Perla pallida*	Guérin-Méneville, 1838

this study, *I. bithynica* was closely related to dissolved oxygen and pH in CCA diagram.

Quadrant B

L. aspoeckorum and *P. microcephalus* were related to Zn, NO_2 and Ca hardness in Quadrant B (Fig. 5). *N. cinerea turcica* was located closer to the center of the CCA diagram. This result indicated that none of the variables used in the CCA diagram affected this species occurrence in collecting sites. Plecoptera species are resistant to the effects of zinc (Jones 1958). Jones (1958) stated that *Leuctra* and *Nemoura* were abundant close to the zinc mine in Ystwyth River. The zinc concentration in the river was high and was up to 1.2 mg/L. The chronic influence of zinc on freshwater insects is indicated between 0.05 and 0.1 mg/L (IPCS 2001). In this research, zinc concentration was between 0.01 and 0.1 mg/L, while zinc concentration was 0.09 mg/L in collecting site of *L. aspoeckorum* and *P. microcephalus*. *Leuctra aspoeckorum* is an inhabitant of hypocrenon, epirhithron and metarhithron. This species also prefers streams in alpine region (2400–2900 m) (Zhitzova 2003). These data are compatible with properties of the collecting site in this study. Khazeeva (2010) reported *P. microcephalus* from brooks of unpolluted upstream region of Urukh River Basin (Northern Slopes of the Central Caucasus). *P. microcephalus* prefers oligosaprobic and beta-mesosaprobic environments mainly, but it was also found in xenosaprobic and alpha-mesosaprobic environments (Graf et al. 1995, 2002). In this research, *P. microcephalus* was recorded from headwaters of İkizdere Stream. Graf et al. (1995, 2002) reported that the stream zonation preference of this species is epirhithron mainly, but metarhithron, hiporhithron, epipotamon and metapotamon can be found. In this study, this species was recorded headwater (hypocrenon) streams. Khazeeva (2010) reported *N. cinerea* from Urukh River Basin (Northern Slopes of the Central Caucasus) which is slightly affected by pollution. *N. cinerea* was recorded from unpolluted upstream region and slightly polluted downstream (piedmont) region Khazeeva (2010). The environmental preferences of *N. cinerea turcica* are unknown.

Quadrant C

B. transcaucasica transcaucasica, *L. sipahilerae*, *N. taurica*, *N. martynovia*, *P. bacurianica bacurianica* and *P. sakartvella* were related to Cu and Mg hardness in Quadrant C (Fig. 5). The negative effects of low concentrations (as low as 5 µg/L) of Cu on benthic macroinvertebrate species richness were reported (Leland et al. 1986). According to USEPA (1984), total dissolved copper concentration should be less than 0.01 mg/L for conservation of aquatic life. According to USEPA (2005), the limit values of copper for aquatic life fluctuate in the range 0.0065–0.021 mg/L. The highest concentration of Cu was 0.06 mg/L in this study. Cherchesova et al. (2012) reported *B. transcaucasica* from the upper reach of Nalchik-river and from the polluted glacial river Urukh in Kabarda-Balkarian Republici the Central Caucasus. According to Cherchesova et al. (2012), *B. transcaucasica* is able to live in polluted running waters. In this study, *B. transcaucasica transcaucasica* was recorded from Site 3 and Site 4. The water quality of these sites was high according to nitrate (0.045 mg/L in Sites 3 and 4) and nitrite (0.0012 mg/L in Site 3 and 0.0021 mg/L in Site 4). Concentration of Cu was higher (0.03 mg/L in Site 3 and 0.06 mg/L in Site 4), and *B. transcaucasica transcaucasica* was closely related to Cu in CCA diagram. *L. sipahilerae* was also closely related to Cu and Mg hardness in CCA diagram. This species was recorded from headwaters of Altındere Stream and from main stem of Altındere Stream in Maçka, Trabzon. *L. sipahilerae* is an endemic species in Eastern Black Sea Region. The ecological knowledge of *L. sipahilerae* was given in the present study, for the first time. Khazeeva (2010) reported *N. martynovia* from Urukh River Basin (Northern Slopes of the Central Caucasus) which is slightly affected by pollution. *N. martynovia* was recorded from unpolluted upstream region and slightly polluted downstream region. The saprobic preferences of *N. taurica*, *N. martynovia*, *P. bacurianica bacurianica* and *P. sakartvella* are unknown. The knowledge of saprobic preferences of these species was given in the present study, for the first time.

Quadrant D

I. grammatica, *P. microstyla*, *L. minuta minuta* and *N. carpathica* were related to conductivity, Al, Fe^{2+} and temperature in Quadrant D (Fig. 5). *M. vitripennis* was recorded in Site 14 on Çekerek Stream which was one of the main tributaries of Yeşilırmak River affected by anthropogenic activities (Kazancı et al. 2012). Site 14 was located separately from other sites by different habitat structures and by different physicochemical characteristics. *M. vitripennis* was recorded only in this site as the indicator species. Moroz et al. (2006) reported *I. grammatica* from hypopotamon of Berezina River in Belarus. Berezina River has high content of iron (1.08 mg/L), and the mineralization of water varies between 240 and 330 mg/L in the high water seasons. The ecological characteristics of Berezina River indicated that *I. grammatica* prefers environments with high temperature, high conductivity and high concentration of iron. According to the results of CCA diagram, *I. grammatica* was related to conductivity, Al, Fe^{2+} and temperature in this study. In collecting site of *I. grammatica* (Site 1), pH was 6 and conductivity was 523 µS/cm. According to these results, *I. grammatica* can live in a disturbed environment. Dow and Zampella (2000) reported that the joint and individual use of pH and conductivity data could provide a quick assessment of the watershed disturbance variability among sites. Daniel et al. (2002) showed that the average value of conductivity in pristine sites was between 50 and 100 µS/cm and in the most disturbed sites was between 400 and 600 µS/cm. They also assumed a conductivity of 250 µS/cm as an intermediate value of urban land use effects. *L. minuta minuta* was the recorded from Site 1 and Site 5. These sites were impacted by anthropogenic activities. In Site 1, pH was 6.5 and conductivity was 287 µS/cm, and in Site 5 pH was 5.5 and conductivity was 38 µS/cm. According to these results, *L. minuta minuta* can live in an environment which is slightly or moderately impacted by human activities. The saprobic preferences of *P. microstyla* and *L. minuta minuta* are unknown. The knowledge of saprobic preferences of these species was given in the present study, for the first time. *N. carpathica* prefers xenosaprobic and oligosaprobic environments (CSN 75 (7716) 1998; Sporka 2003). In this research, *N. carpathica* was closely related to the water temperature.

TWINSPAN grouping

P. bacurianica and *N. martynovia* were the indicators of Sites 14, 6, 9, 24, 3, 4, 10, 2, 11, 15, 1 and 5. *M. vitripennis*

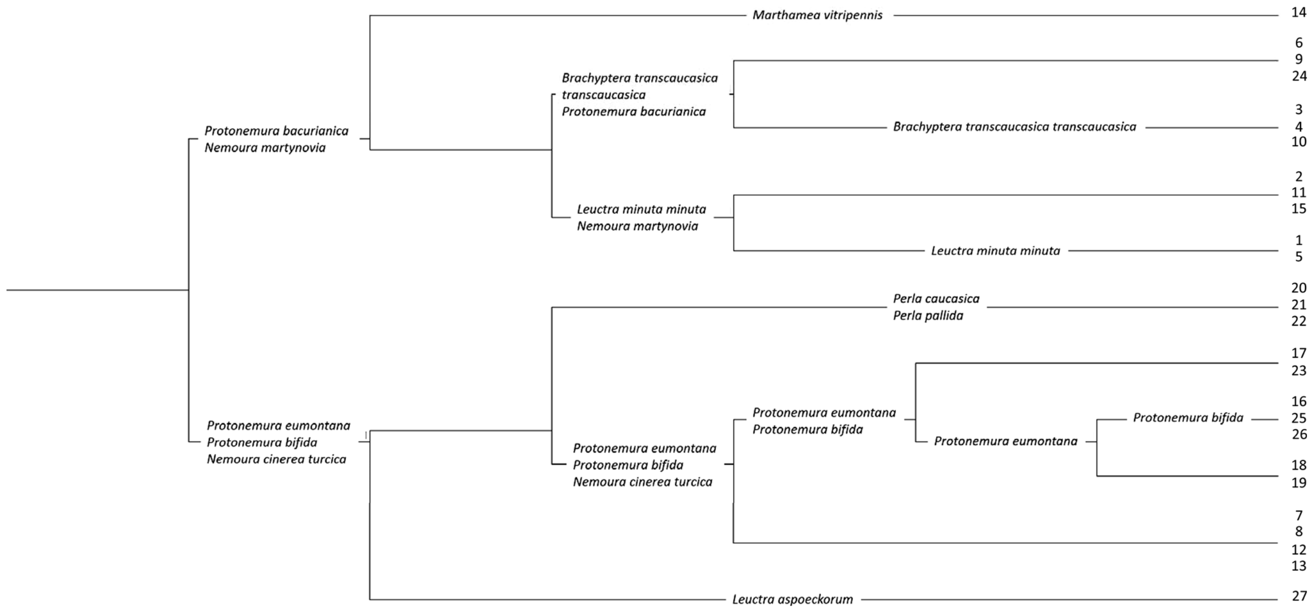

Fig. 6 TWINSPAN grouping of sites and indicator Plecoptera species

was the indicator of Site 14 on Çekerek Stream which was one of the main tributary of Yeşilırmak River affected by anthropogenic activities and has a different habitat structure (Kazancı et al.2012). Site 14 was located separately from other sites by different habitat structure and by different physicochemical characteristics in CCA and TWINSPAN. *M. vitripennis* was recorded in this site as the indicator species. *B. transcaucasica transcaucasica* and *P. bacurianica* were the indicators of Sites 6, 9, 24. *B. transcaucasica transcaucasica* was the indicator of Sites 3, 4 and 10. *L. minuta minuta* and *N. martynovia* were the indicators of Sites 2, 11 and 15. The conductivity of Sites 2, 11 and 15 was 145, 556 and 709 µS/cm, respectively. According to Daniel et al. (2002), these electrical conductivity values indicate disturbed habitats. Therefore, these sites were influenced by anthropogenic disturbances. *L. minuta minuta* was the indicator of Site 1 and Site 5. These sites were slightly impacted by anthropogenic activities except Sites 6 (pH was 5, and conductivity was 99 µS/cm) and 15 (pH was 6.69, and conductivity was 709 µS/cm). *P. eumontana*, *P. bifida*, *N. cinerea turcica* were the indicators of Sites 20, 21, 22, 17, 23, 16, 25, 26, 18, 19, 7, 8, 12, 13 and 27. *P. caucucasica* and *P. pallida* were the indicators of Sites 20, 21 and 22. These sites were on the main stem of Fırtına Stream, and their physicochemical and hydromorphological characteristics were similar. These sites were not influenced by human impacts. *P. eumontana* and *P. bifida* were the indicators of Site 17 and Site 23. *P. eumontana* was also the indicator of Sites 18 and 19, which were unimpacted headwaters of Fırtına Stream. *P. bifida* was also the indicator of Sites 16, 25 and 26 on headwaters of İkizdere Stream. The physicochemical and hydromorphological characteristics of these sites were similar to dense riparian vegetation without human impacts. *L. aspoeckorum* was the indicator species of Site 27 without human impacts. This site was located in the headwater region of İkizdere Stream.

Conclusion

Various anthropogenic activities threaten the aquatic fauna of running waters. In particular, rhithral region of running waters which contains reference habitats is much more sensitive to global climate change and sensitive macroinvertebrate taxa might disappear due to the increase in temperature and floods. Many Plecoptera species that are adapted to cold waters of upstream regions are severely threatened by global climate change.

The physical disturbance due to floods and agricultural pollution as a result of intensive tea plantation are the most effective reasons of habitat degradation of running waters and diversity loss of Plecoptera in Eastern Black Sea Region.

Detailed information about Plecoptera fauna and ecological preferences of species is necessary in the preparation of ecoregional biotic indices. The currently available knowledge on the effects of different environmental variables on the community structure of Plecoptera species is not sufficient. This research will be helpful to complete some of the missing ecological information of Plecoptera species.

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