

New Data on Ephemeroptera, Plecoptera and Trichoptera from the Republic of Macedonia

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Abstract: As a result of field survey carried out in 2007-2014 at 18 sampling points at rivers of the Republic of Macedonia, new data on the distribution of four species of the order Ephemeroptera (*Serratella ikonovski*, *Ephemerella mucronata*, *Heptagenia longicauda* and *Caenis pseudorivulorum*), two species of the order Plecoptera (*Brachyptera beali beali* and *Taeniopteryx hubaulti*) and one species of the order Trichoptera (*Thremma anomalum*) were collected. These data allow assessment of the conservation status of the studied species. This is the first record of the mayfly *Caenis pseudorivulorum* Keffermüller, 1960 in the Republic of Macedonia.

Key words: EPT, distribution pattern, conservation, Macedonia

Introduction

Freshwater ecosystems are of exceptional interest because they are among the most diverse habitats on earth. It is widely recognised that rapid globalisation has caused wide-spread degradation and disruption of natural systems, especially in the freshwater realm (LÉVÊQUE *et al.* 2005). Declines in biodiversity are far greater in freshwaters (lakes, rivers and wetlands) than in the most affected terrestrial ecosystems (DUDGEON *et al.* 2006). According to the IUCN Red Lists of threatened species (IUCN 2015) and ABELL *et al.* (2008), a quarter of the known worldwide freshwater species are listed as threatened or regionally extinct. Thus, the knowledge of the distribution and population status of the majority of aquatic species is urgently needed to understand and protect freshwater ecosystems worldwide (MÄCHLER *et al.* 2014).

On the other hand, the present knowledge of freshwater diversity is still partial. According to a rough estimate by BALIAN *et al.* (2008), 60.4% of

freshwater animal species are insects. Trichoptera, Plecoptera and Ephemeroptera (usually known as EPT taxa) represent 15%, 5% and 4%, respectively, of the total number of freshwater animal species (BALIAN *et al.* 2008). These organisms are essential elements in the benthic communities playing an important role in the nutrient cycling of materials and in trophic transfers (FERRO, SITES 2007). As EPT taxa are generally sensitive to environmental perturbations, they are widely used for ecological monitoring (ROSENBERG, RESH 1993).

The vulnerability to variation in abiotic factors (pollution, habitat degradation, acidification, climate change, etc.) may lead to local or global extinction of many EPT species (SLAVEVSKA-STAMENKOVIĆ *et al.* 2011, HERSKOVITZ *et al.* 2015). In this regard, EPT species belong to the category of the most endangered aquatic insects (HERING *et al.* 2009, PETROVIĆ *et al.* 2014, 2015). However, globally there are only

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11 (seven Extinct, two Vulnerable, one Endangered and one Critically Endangered) EPT taxa included in the IUCN Red Lists for threatened species (IUCN 2015). The larvae of EPT species, as well as of the other aquatic invertebrates are notoriously difficult to inventory because of their small size, often low population densities and patchy distribution (MÄCHLER *et al.* 2014), which probably contributes to their low level of conservation.

Compared to Western and Central Europe (e.g., GRAF *et al.* 2008, 2009; BUFFAGNI *et al.* 2009), scarce information on the distribution and conservation status of EPT taxa from the Balkan Peninsula is available (IBRAHIMI *et al.* 2012, 2014, TYUFEKCHIEVA *et al.* 2013, PETROVIĆ *et al.* 2014, 2015). In the Republic of Macedonia, previous studies have been mainly focused on the taxonomy of EPT taxa. Ephemeroptera have been extensively examined by IKONOMOV (1951, 1953, 1954 a, b, c, 1958, 1960, 1961 a, b, 1962 a, b, c, d, 1963 a, b, 1964, 1970) and, more recently, by VIDINOVA (1998), SMILJKOV, SLAVEVSKA-STAMENKOVIĆ (2004) and SMILJKOV *et al.* (2008).

There are numerous publications dealing with Macedonian stoneflies (Plecoptera), especially from

the last century (IKONOMOV 1969, 1970, 1971, 1972, 1974 a, b, 1975, 1976 a, b, 1977, 1978, 1979, 1980 a, b, 1982, 1983 a, b, c, 1986 a, b, ZWICK 1984). Recently, a new species of stonefly, *Siphonoperla korab* Graf, 2012, was described (GRAF *et al.* 2012) and four new taxa (*Nemoura anas* Murányi, 2007, *Leuctra graeca* Zwick, 1978, *Zwicknia acuta* Murányi & Orci, 2014 and *Isoperla pesici* Murányi, 2011) for the Republic of Macedonia were recorded (MURÁNYI 2007, MURÁNYI *et al.* 2014).

Compared to mayflies and stoneflies, Trichoptera (caddisflies) is relatively insufficiently known insect order in Macedonia (RADOVANOVIĆ 1942, BOTOSANEANU 1960; PAVLOVSKI 1991, ARSOV 1991, KUMANSKI 1997, KUMANSKI, MALICKY 1999). Considerable progress has been made in recent years and new taxa were described (OLÁH 2010, OLÁH *et al.* 2011, 2013 a, b, OLÁH, KOVÁCS, 2013, 2014, OLÁH *et al.* 2014, VITECEK *et al.* 2015).

Although historical data are of great importance, future changes in the composition of the EPT taxa in Macedonia will go undetected unless current distribution of existing species is well documented. Thus, the aim of this paper is to report new data on

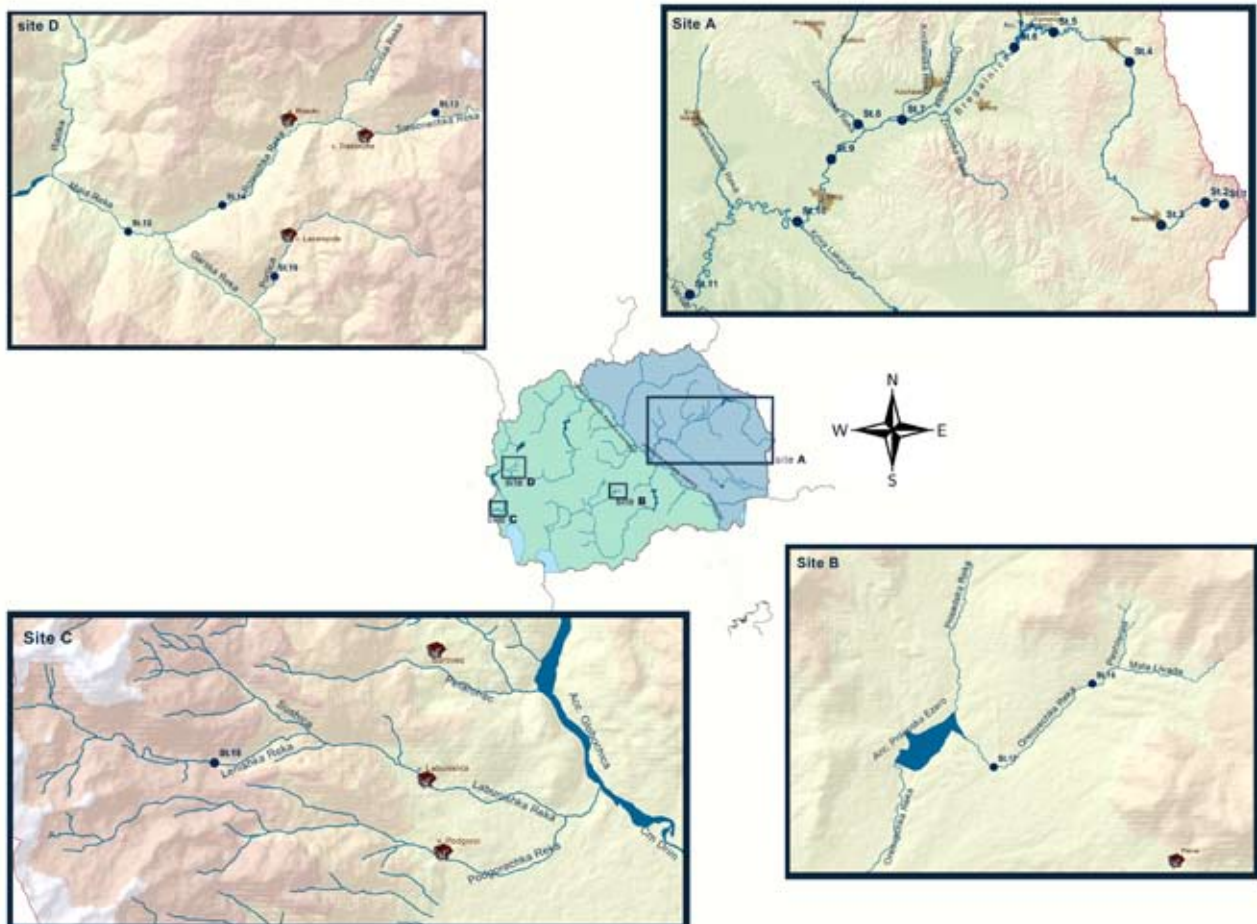


Fig. 1. Localities of the studied water bodies

Table 1. Characteristics of the sampling sites

Code	River/Locality	Altitude (m)	Longitude (°N)	Latitude (°E)	Ecoregion	Sampling period
Site A Bregalnica River						
S1	Dve Reki	1 300	41°43'37.5"	22°59'16.5"	7	October 2008-September 2009
S2	Ramna River	1 100	41°43'52.6"	22°56'56.3"	7	October 2008-September 2009
S3	upstream Berovo	856	41°41'59.8"	22°51'27.9"	7	October 2008-September 2009
S4	upstream Dechevo	601	41°56'32.5"	22°48'15.7"	7	October 2008-September 2009
S5	upstream Kalimanci dam	536	41°59'20.8"	22°39'16.9"	7	October 2008-September 2009
S6	downstream Kalimanci dam	420	41°58'03.6"	22°34'32.4"	7	October 2008-September 2009
S7	v. Teranci	317	41°51'45.4"	22°20'58.5"	7	October 2008-September 2009
S8	mouth of Zletovica River	296	41°51'32"	22°15'51"	7	October 2008-September 2009
S9	v. Dolni Balvan	282	41°48'21"	22°12'12"	7	October 2008-September 2009
S10	v. Sofilari	257	41°42'34"	22°8'12"	7	October 2008-September 2009
S11	mouth of Bregalnica to Vardar	154	41°36'24.344"	21°55'23.011"	7	October 2008-September 2009
Site D						
S12	Mala Reka River	735	41°32'9.888"	20°38'25.987"	6	April 2011
S13	Tresonechka River	1150	41°34'2.03"	20°44'46.895"	6	April 2011
S14	Rosochka River	810	41°32'35.07"	20°40'22.729"	6	April 2011
S15	Portica (Lazaropolska) River	1170	41°31'28.85"	20°41'27.81"	6	April 2011
Site B Orevovechka River						
S16	downstream the local fishpond	860	41°23'48.32"	21°38'2.75"	6	March 2011, March 2012
S17	upstream entering Prilep Reservoir	740	41°23'1.971"	21°36'48.361"	6	March 2011, March 2012
Site C Lenishka River						
S18	upstream course	1455	41°16'18.609"	20°33'13.628"	6	July 2014

some rare and endemic EPT taxa collected during the last years in the Republic of Macedonia, thus improving the knowledge on their geographic distribution and assisting to make a preliminary assessment of their conservation status.

Material and Methods

We present part of the results from the survey of 18 sampling points (Fig. 1) classified as: Site A - Bregalnica River (S1-S11); Site D - Mala Reka River (S12), Tresonechka River (S13), Rosochka River (S14), Portica (Lazaropolska) River (S15); Site B - Orevovechka River (S16-S17) and Site C - Lenishka River (S18). Data for the geographical coordinates, altitude, sampling period and ecoregion (according ILLIES 1978) for each locality is presented in Table 1.

The field survey was carried out between October 2007 and July 2014. Aquatic macroinvertebrates were collected with Surber sampler and hand-net with mesh size 500 µm, and in some cases

(for coarse sand and silt substrata) an Ekman grab. Standard methodology for collection of bottom fauna (EN 28265:1994, EN 27828:1994, EN 9391:1995) was followed. EPT larvae specimens were separated from the other organisms, preserved in 80% ethanol and deposited in the Macedonian National Collection of Invertebrates (MNCI), Faculty for Natural Science and Mathematics, Skopje, R. Macedonia. The keys of AUBERT (1959), EDIGTON, HILDREW (1981), ELLIOT *et al.* (1988), HYNES (1977), WARINGER, GRAF (1997, 2013), WALLACE *et al.* (2003) and ZWICK (2004) were used for identification of the EPT larvae. The systematic presentation follows DE JONG *et al.* (2014) and BAUERNFEIND, SOLDAN (2012).

Abbreviations of collectors: BR=Biljana Rimcheska, VS=Valentina Slavevska-Stamenković.

Results

Ephemeroptera

Serratella ikonovski (Puthz, 1971)

Material studied: Bregalnica River, S3:

25.V.2008: 22 la, 28.VI.2008: 8 la, 24.VII.2008: 3 la, leg. VS (MNCI).

Ephemerella mucronata (Bengtsson, 1909)

Material studied: Bregalnica River, **S1:** 10.X.2007: 2 la, 15.XI.2007: 4 la, 24.XII.2007: 3 la, 21.I.2008: 1 la, 15.II.2008: 1 la, 25.III.2008: 11 la, 27.IV.2008: 27 la, 25.V.2008: 2 la, 28.VI.2008: 4 la, 22.VIII.2008: 3 la, 01.XI.2008: 2 la; **S2:** 15.II.2008: 2 la, 25.III.2008: 1 la, 27.IV.2008: 1 la, 25.V.2008: 3 la, 24.VII.2008: 2 la, 22.VIII.2008: 5 la, leg. VS (MNCI).

Heptagenia longicauda (Stephens, 1835)

Material studied: Bregalnica River, **S11:** 01.XI.2008: 7 la, leg. VS (MNCI).

Caenis pseudorivulorum Keffermüller, 1960

Material studied: Bregalnica River: **S3:** 22.VIII.2008: 1 la; **S5:** 25.V.2008: 18 la, 28.VI.2008: 16 la, 22.VIII.2008: 26 la, 18.IX.2008: 46 la; **S6:** 28.VI.2008: 229 la; **S7:** 10.X.2007: 1 la; **S8:** 10.X.2007: 5 la, 28.VI.2008: 19 la, 24.VII.2008: 19 la, 22.VIII.2008: 2 la, 18.IX.2008: 1 la; **S9:** 28.VI.2008: 31 la, 22.VIII.2008: 18 la, 18.IX.2008: 2 la; **S10:** 10.X.2007: 1 la, 15.XI.2007: 2 la, 28.VI.2008: 15 la, 24.VII.2008: 18 la, 22.VIII.2008: 9 la; **S11:** 15.XI.2007: 1 la, 25.V.2008: 1 la, 28.VI.2008: 14 la, 22.VIII.2008: 1 la, 18.IX.2008: 2 la, leg. VS (MNCI).

Note: New species for the fauna of the Republic of Macedonia.

Plecoptera

Brachyptera beali beali (Navás, 1924)

Material studied: Orevovechka River, **S17:** 24.III.2011: 1 la, **S18:** 24.III.2011: 13 la, 18.III.2012: 125 la, leg. BR (MNCI).

Taeniopteryx hubaulti Aubert, 1946

Material studied: Bregalnica River, **S6:** 24.XII.2007: 1 la, leg. VS (MNCI).

Trichoptera

Thremma anomalum McLachlan, 1876

Material studied: Mala Reka River, **S12:** 19.IV.2011: 1 la; Tresonechka River, **S13:** 19.IV.2011: 2 la; Rosochka River, **S14:** 19.IV.2011: 4 la; Portica (Lazaropolska) River, **S15:** 19.IV.2011: 3 la; Lenishka River, **S18:** 13.VII.2014: 1 la, leg. VS (MNCI).

Discussion

Our study shows that in Macedonia there are still unexplored areas concerning mayfly species. During the comprehensive survey of macroinvertebrate fauna from Bregalnica River, the presence of new and

rare mayfly species was confirmed. Among them, *Caenis pseudorivulorum* Keffermüller, 1960 presents a Ponto-Caspian faunal element widespread all over Europe (BAUERNFEIND, SOLDAN 2012). Even though previously known from Bulgaria (VIDINOVA 2003), Greece (BAUERNFEIND 2003) and Serbia (PETROVIĆ *et al.* 2015), until now this species has not been reported from Macedonia. The finding of this species in the middle and lower part of Bregalnica River (from S5 to S11), confirms its affinity to the potamal of large rivers with gravel and sandy microhabitats (BUFFAGNI 1997, 1999, 2003, VIDINOVA 2003). The records of *C. pseudorivulorum* in Macedonia contribute to the better knowledge of its distribution range on the Balkan Peninsula.

The mayfly *Serratella ikonovici* (Puthz, 1971) was observed in the waters of several countries in Southern European, such as Bosnia and Herzegovina (TANASIJEVIĆ 1979), Serbia (STUEMANN *et al.* 1989, SIMIĆ, SIMIĆ, 2003, SAVIĆ *et al.* 2010), Albania (STUEMANN *et al.* 1989), Greece (STUEMANN *et al.* 1989, BAUERNFEIND 2003), Italy (BUFFAGNI *et al.* 2003) and Spain (LÓPEZ-RODRÍGUEZ *et al.*, 2008), but never from Ecoregion 7 (Eastern Balkans). In the Republic of Macedonia, this species was previously reported from several streamlets from the western part (Ecoregion 6 - Hellenic Western Balkans) of the country (IKONOVIC 1961, STUEMANN *et al.* 1989). In the current study, larvae of this rare species were found on stony substrate in the Upper Bregalnica River (S3; Fig. 1), which is the first finding of *S. ikonovici* for the Ecoregion 7 (ILLIES 1978). Based on the fact that this Mediterranean faunistic element inhabits higher altitudes along the Bregalnica River (856 m a.s.l.), we presume that the region is under increasing influence of Mediterranean climate.

The rheophilic mayfly *Ephemerella mucronata* (Bengtsson, 1909) is widespread in Europe (with the exception of the British Inlands and the Iberian Peninsula), oriental regions of the former USSR and North America (BELFIORE *et al.* 1990, BAUERNFEIND, SOLDAN 2012). Concerning the Republic of Macedonia, scarce populations of the species were recorded by IKONOVIC (1961) from three springs of the Baba and Osogovo Mountains. A field survey conducted on the upper course (S1 and S2; Figure 1) of Bregalnica River revealed that this rare mayfly inhabits Maleshevski Mountains too. These localities are the easternmost populations of *E. mucronata* in the Republic of Macedonia.

Another rare mayfly, *Heptagenia longicauda* Stephens 1835, is a well known species from the Western Palearctic (BAUERNFEIND, SOLDAN 2012).

Previously it was recorded by IKONOMOV (1963a) from the middle and lower course of Vardar River. In the current study, few larvae of *H. longicauda* were collected from the stone bedrocks and submerged logs and plants at S11 (mouth of Bregalnica into Vardar River), although we expected it at locality S9 and S10 which also belong to the lower part of the river. Despite its eurivalence to the most of ecological factors (MACADAM 2003), *H. longicauda* usually avoids places with α -mesosaprobic conditions (VIDINOVA, RUSSEV 1997, BAUERNFEIND, SOLDAN 2012). Another reason for the restricted distribution of the heptageniid population in the lowland parts of many European rivers is the gravel extraction in the catchments, which alters the aquatic environment, and in many cases causes total loss of habitat (MACADAM 2006). This could be a possible explanation for the extinction of *H. longicauda*, from the sampling point S9 (gravel extraction) and S10, one of the most polluted sites on the Bregalnica River (SLAVEVSKA-STAMENKOVIĆ, unpublished data).

The results of this study provide new data for the distribution of two rare Plecoptera species in the Republic of Macedonia: *Brachyptera beali beali* (Navás, 1924) and *Taeniopteryx hubaulti* Aubert, 1946. From a zoogeographical point of view, *B. beali beali* is a Balkan endemic stonefly (GRAF *et al.* 2009) reported from Bosnia and Herzegovina (MURIĆ *et al.* 2011), Greece (AUBERT 1963, BERTHÉLEMY 1971, ZWICK 1978) and Montenegro (MURÁNYI 2008). According to IKONOMOV (1983 b, 1986 b) and recently to MURÁNYI *et al.* (2014) *B. beali beali* inhabits few springs in Southern Macedonia. Currently, Orevoevchka River presents the northernmost point of its known distribution in the country.

The rheophilic stonefly *Taeniopteryx hubaulti* is an European species. According to GRAF *et al.* (2009) it is known from Ecoregions 2 (Pyrenees), 4 (Alps), 5 (Dinaric Western Balkans), 6 (Hellenic Western Balkans), 7 (Eastern Balkans), 8 and 9 (Western and Central Highlands) and 10th (Carpathians). In Macedonia, the larvae of the stonefly *T. hubaulti* were previously reported only from the Brajchinska River (IKONOMOV 1974). In the current study its presence (a single larvae specimen) was recorded at site S6. Bregalnica River, after Kalimanci Dam is characterised with high current speed, colder water during the year, low fluctuation of temperature and high oxygen saturation which offers optimal conditions for its occurrence. Additionally, the restricted area and the fact that larvae were not collected during the last 50 years suggest that, if the species exists it is particularly rare; perhaps under higher risk of extinction, or that larvae occupy an unusual habitat which

has not been sampled. Similar conservation status of the species was determined in the neighbouring countries Bulgaria and Serbia (TYUFEKCHIEVA *et al.* 2013, PETROVIĆ *et al.* 2014).

The caddisfly *Thremma anomalum* McLachlan, 1876 is a subendemic species for Balkan Peninsula, Carpathians and Caucasus (GRAF *et al.* 2008, ŽIVIĆ *et al.* 2013). So far in Europe the species was known from Ecoregions 5, 6, 7, 10 and 24 (OLÁH, KOVÁCS 2013, ŽIVIĆ *et al.* 2013, IBRAHIMI *et al.* 2014). Additionally, *T. anomalum* was found by SİPAHLER (2007) from the Asian part of Turkey, which belongs to Ecoregion Y (Asia Minor).

In the Republic of Macedonia the adult stage of *T. anomalum* has been reported from Shar Planina Mountains (KUMANSKI 1997, OLÁH, KOVÁCS 2014) and Pelister (RADOVANOVIĆ 1942), and larvae were recorded from Podgorecka River, Jablanica Mts. (RADOVANOVIĆ 1942). In the current study limited numbers of specimens (11) of *T. anomalum* were found. Despite intensive research performed by SLAVEVSKA-STAMENKOVIĆ (unpublished data) on the Jablanica Mts, reported as area for protection (BIODIVERSITY STRATEGY AND ACTION PLAN OF THE REPUBLIC OF MACEDONIA, 2004), a single larvae specimen was registered (Lenishka River, S18). It should be stressed that the spring areas, upper courses of the streams and streamlets on this mountain are under higher anthropogenic pressure, and especially abstraction of water, which probably caused the disappearance of *T. anomalum*. The other ten larvae were found in Mawla Reka River (S12), Tresonecka River (S13), Lazaropolska River (S15) and Rosocka River (S14) that belong to the „Mavrovo“ National Park. Restricted distribution range in the country and scarce populations, especially in the Jablanica Mts., suggest that *T. anomalum* belongs to the group of threatened caddisfly species in the Republic of Macedonia. The similar population trend of this taxon is registered in some of our neighbouring countries. Namely, recent study in Western Serbia and Northern Montenegro has not recorded this species, in spite of its previous presence (ŽIVIĆ *et al.* 2013).

Conclusion

Our results highlight the importance of new surveys in the area in order to assess the overall biodiversity of this group of aquatic insects and to estimate population status or extinction rates of the EPT taxa according to IUCN criteria. Obtained data could be useful for selection the regions of high conservation values where effective protection measures should be applied.

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