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Distribution and Ecology of Taeniopterygidae (Insecta: Plecoptera) in Bulgaria

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Abstract: Data about the distribution and ecology of 17 Taeniopterygidae species in Bulgaria are given in this study. The geographical distribution, based on a literature survey and available collection is presented with UTM codes and maps. Various hydro- ecological characteristics for every particular species are summarized and commented. Among the 17 species that have been recorded, one is regionally extinct (RE) from the country, 9 – critically endangered (CR), 3 – endangered (EN) and one is vulnerable (VU). From a zoogeographical point of view, 4 species from the Taeniopterygidae, recorded in Bulgaria, are endemics: *Brachyptera thracica* is a Bulgarian endemic (only in the Rhodopes Mts.) and *B. bulgarica*, *B. helenica* and *Rhabdiopteryx triangulari* are Balkan endemics. The correlations of seven Taeniopterygidae species with corresponding environmental data were analyzed using direct multivariate technique (CCA). A large majority of environmental factors showed significant correlations, but the strongest were those with the altitude, substrate types and oxygen content, tested additionally by a nonparametric Spearman rank order correlation.

Key words: Taeniopterygidae, Plecoptera, Bulgaria, distribution, ecology

Introduction

Plecoptera order is comparatively well studied in Bulgaria. We have good taxonomic knowledge, but the ecological data for most known stonefly species are insufficient. Navas (1929) who reported *Brachyptera seticornis* (Klapálek 1902) as *Taeniopteryx seticornis* from Vitosha and Rila mountains gave the first data of Taeniopterygidae family in Bulgaria. Later on summary faunistic data from Bulgarian rivers are also reported (Buresch 1936, Rauser 1962, 1965, Braasch, Joost 1971 a, b, c, 1972, 1975, Vidinova *et al*. 2000). Kumanski (1997, 2004), Gueorguiev *et al*. (1998), Hubenov *et al*. (2000 a, b) generalized the known data for some of the biggest National parks in the country like Pirin, Rila, Central Balkan and Eastern Rhodopes. The majority of the results in the hydrobiological research are focused on the Danube River and its tributaries (Russev 1962, 1966, 1971, 1979, Janeva 1987, Janeva, Russev 1989, Russev *et al*. 1991). The other data belong to the watercourses in South Bulgaria: Blagoevgradska Bistritsa, Strouma, Mesta, Arda, and Tundzha rivers. They include not only the faunistic diversity data (Janeva, Russev 1985, Uzunov, Varadinova 2001, Sakelarieva *et al*. 2008, Vidinova *et al*. 2008), but also ecological characteristics of the rivers (Russev 1967, Russev, Janeva 1975, Nachev 1982, Russev *et al*. 1984, Janeva, Bancheva, 2002, Sakelarieva, Janeva, 2006).

So far, there are quite some studies on species distribution and ecological preferences of Taeniopterygidae family in Europe (Ravizza, Fochetti 1999, Graf, Hutter 2003, Krno 2004,

Kovacs, Muranyi 2008, Muranyi 2008, Graff *et al*. 2009, Vinçon, Murányi 2009, Bojkova *et al*. 2011).

In present study the new data are a part of Supplemental Water Quality Survey (2006) as well as from limnological research on macrozoobenthic communities concerning some activities for the implementation of WFD (2000/60/EC) especially regarding water bodies' typology in Bulgaria.

The aims of this paper were: (i) to summarize both literature and unpublished data and to present contemporary status on the distribution and ecology of each Taeniopterygidae species in Bulgaria, (ii) to present the interactions of some species with environmental factors, and (iii) to classify Bulgarian Taeniopterygidae species according to IUCN categories.

Material and Methods

Universal Transverse Merkator (UTM) codes on each Taeniopterygidae species are prepared by Bulgarian UTM Directory computer programme (Michev 1999). Published records are presented by literature sources and UTM code numbers. Unpublished and new data of individual records are listed in details: code number, name of watercourse, day, month and year. The new data based on unpublished material are currently available at the Institute of Biodiversity and Ecosystem Research, BAS (IBER-BAS, Sofia). Some records which are part of unpublished protocols by Prof. B. Russev (det. by Dr. D. Braasch) are also included.

Samples were collected by the standard methods ISO 7828/1985 and ISO 8265/1988. A total of 190 samples (from literature records and unpublished material) were taken from watercourses both of small rivers and of some large rivers like Danube, Iskar, Maritsa, Tundzha and Mesta in the period 1962-2011, except 11 samples in the period 1910-1957. The data of physico-chemical parameters (Table 1) are in a result of standard water chemistry analyses. The saprobiological state of the rivers is determined with the method of saprobic valences of Zelinka, Marvan (1961) and Rothschein (1962). The ecological requirements refer to Graf *et al*. (2009).

The multivariate Canonical Correspondence Analysis (CCA) from the computer programme package CANOCO 4.5 (ter Braak, Šmilauer, 2002) and StatSoft STATISTICA 7.0 were applied to determine the relations of selected environmental parameters from 30 samples with some Taeniopterygidae species.

Results

Environmental factors

The range of measured physico-chemical parameters for each of the seven species is presented in Table 1.

The data about the rest 10 species were uncompleted. Typically for Plecoptera as biological indicators of good watershed quality, the values of oxygen content (both in mg and %) were high, nutrient concentrations (N and P) and oxidability were low, while pH values rarely exceeded 8.0 and water temperatures were under 15 °C. Stream zonation preferences of each of the 17 species are shown in Table 2.

Frequently preferred zones were epi- and metarhithral. Altitude ranges of all 17 species are presented in Fig. 1.

Chorological records and ecology of Taeniopterygidae species

Genus *Taeniopteryx* Pictet 1841

Taeniopteryx auberti Kis, Sowa 1964 (Fig. 2)

Literature records: Braasch, Joost 1971a: 269, FN82; Braasch, Joost 1975: 167, FN82, GM18, LH12; Russev, Janeva 1975: 24, LG02; Hubenov *et al*. 2000b: 319, GM17.

Unpublished data (det. by Dr. D. Braasch): FN82, Vladaiska River, 13.09.1973; GM08, Cherni Iskar River, above Vada hut, 12 – 16.10.1969.

T. auberti is a stenoecic species, which inhabits stones, gravel (mesolithal) and sunk higher vegetation in subalpine and montane Bulgarian rivers. It has been found at oligosaprobity (S_R = 80.66) and belongs to the typical rheophil species.

Taeniopteryx hubaulti Aubert 1946 (Fig. 2)

Literature records: Russev 1971: 112, GM18; Janeva, Russev 1989: 7, FN91; Russev *et al*. 1991: 20, FP42; Gueorguiev *et al*. 1998: 174, FP42; Sakelarieva *et al*. 2008: 207, FM85.

Unpublished data: GM02, Duilovets River, Pirin Mountain, 07.11.1970; GM28, Maritsa River, 21.09.1991; KG82, Devinska River, above Devin town (t.), 22.9.1995; GM06, Skakavitsa River, 18.10.1995; GM14, Votrachka River, above Belitsa t., 31.10.1996; GM25, Cherna Mesta River, above

Table 1. Minimum and maximum values of physico-chemical parameters of some Taeniopterygidae species in Bulgaria

Species	Water temp. (ºC)	pH	dH°	Dissolved oxygen ($mg.L^{-1}$)	Oxygen saturation (%)	Oxidability ($KMnO_4$) ($mg.L^{-1}$)	BOD_5 ($mg.L^{-1}$)	NO_2-N ($mg.L^{-1}$)	NO_3-N ($mg.L^{-1}$)	NH_4-N ($mg.L^{-1}$)	PO_4-P ($mg.L^{-1}$)
1. *Taeniopteryx hubaulti* **(Taenhub)**	4.1 – 13.0	7 – 7.6	6.7	9.4 – 10.2	89.9- 95.3	1.52 – 3.2		0.04	0.11 – 1	0.12	0.05 – 0.18
2. *Taeniopteryx nebulosa* **(Taenneb)**	4	8		9.09	98.5	2.08					
3. *Taeniopteryx schoenemundi* **(Taensho)**	2.1 – 15	7.35 – 7.8	11.5 – 12.88	7.52 – 12.96	72.1 – 123.92	1.36 – 5.1		0.16 – 0.22	1.8	0.09 – 0.15	0.01 – 0.04
4. *Brachyptera bulgarica* **(Brachbu)**	1.9 – 6.5	6.8 – 7.5	1.4 – 1.7	11.7 – 13.56	97.14	0.91					
5. *Brachyptera risi* **(Brachri)**	1.6 – 11.8	6.2 – 7.5	0.25	9.8 – 12.8	89 – 99.8	0.66 – 3.78	1.9 – 2.6	0.005 – 0.1	0.16 – 4.1	0.002 – 0.3	0.01 – 0.1
6. *Brachyptera seticornis* **(Brachse)**	1.6 – 13	6.3 – 8	1.4	9 – 14.2	74.11 – 117	1.41 – 5.75	1.9 – 2.79	0.006 – 0.1	0.1 – 2.51	0.02 – 0.3	0.01 – 0.1
7. *Oemopteryx loewii* **(Oemoloe)**	4.4	8		8.99	98.5	1.44					

Cherna Mesta village (v.), 8.11.2005, 11.11.2005; KG07, Yadenitsa River, 14.10.2006, 20.10.2007.

This rheophil species prefers zones with moderate to high current speed. It mainly inhabits akal, mesolithal and macrophytes substrate of rivers and streams. The stenoecic character of the species is proved by the low fluctuations of pH, oxygen saturation, dissolved oxygen and permanganate oxidability. *T. hubaulti* also belongs to the typical indicators of oligosaprobity (S_R from 63.48 to 81.98). We have found larvae of this species mainly in autumn.

Taeniopteryx nebulosa (Linnaeus 1758) (Fig. 2)

Literature records: Russev 1962: 118, LG63; Russev 1966: 106, LG63; Braasch, Joost 1975: 167, KH83; Russev 1979: 324, LG63.

Russev (1962) and Braasch, Joost (1975) reported the species, found respectively on March 3, 1955 in Danube River near Svishtov town and on April 10, 1975 in Stryama River. Recent records are absent. The scanty hydrochemical data (Russev 1962) show that *T. nebulosa* prefers pelal, psammal, macrophytes and fine particulate organic matter from lowland rivers (Danube River) to submontane rivers (Stryama River) in comparatively wide altitudinal limits (from 18 m to 450 m a.s.l.) (Fig. 1). *T. nebulosa* can be regarded as extinct from Bulgarian stretch of Danube River.

Taeniopteryx schoenemundi (Mertens 1923) (Fig. 2)

Literature records: Russev 1971: 112, MH50, MG67; Russev, Janeva 1975: 24, KG80; Russev *et al*. 1984: 64, MH01, MH41, MH50, MG67; Janeva, Russev 1985: 20, MH61, MH41; Vidinova *et al*. 2000: 54, GM27.

Unpublished data: FM83, Senokoska River, Senokos v., 21.10.2010; FM83, Senokoska River, Mechkul v., 21.10.2010, 28.10.2011; FM83, Luda River, 28.10.2011.

T. schoenemundi is typical for sunk higher vegetation (macrophytes), stones and gravel (mesolithal) substrate. It was found in colline, submontane and montane zones inhabited the epipotamal and hyporhitral along Tundzha River (from 100 m to 320 m) and metarhitral zones of Luda, Senokoska (at 750 m), Trigradska and Leeve rivers (from 1300 m to 1900 m), (Table 2, Fig. 1). The species has been found at saprobiological index S_R from 48.00 (β-mesosaprobity) to 80.28 (oligosaprobity). Its resistance to changes in hydrochemical parameters is

Table 2. Stream zonation preferences of Taeniopterygidae species in Bulgaria

Species	hypo-crenal	epi-rhithral	meta-rhithral	hypo-rhithral	epi-potamal	meta-potamal
Rhabdiopteryx triangularis	+	+	+			
Rhabdiopteryx hamulata	+	+	+			
Brachyptera helenica	+	+	+			
Brachyptera risi	+	+	+			
Brachyptera seticornis	+	+	+			
Brachyptera zwicki	+	+	+			
Brachyptera bulgarica	+	+				
Brachyptera thracica	+	+				
Rhabdiopteryx alpina		+				
Taeniopteryx auberti		+	+			
Rhabdiopteryx neglecta neglecta		+	+			
Rhabdiopteryx navicula		+	+			
Taeniopteryx hubaulti		+	+			
Brachyptera braueri			+	+	+	
Taeniopteryx schoenemundi			+	+	+	
Taeniopteryx nebulosa				+	+	+
Oemopteryx loewii					+	+

comparatively high. According to the reported and new investigations, it can be found from March to November. It is a new species for the stonefly fauna of Pirin Mountain.

Genus *Brachyptera* Newport 1851

Brachyptera braueri (Klapalek 1900)

Literature record: *Taeniopteryx braueri*: Buresch 1936: 146, GM38.

Bulgarian occurrence of this species is doubtful. The only literature record on the occurrence of this species in Bulgaria is those by Buresch (1936) who reported *Taeniopteryx braueri* from Kostenetska River. There are not any more data of the species occurrence during the past 100 years.

Brachyptera bulgarica Rauser 1962 (Fig. 3)

Literature records: Rauser 1962: 72, FN72; Braasch, Joost 1971a: 268, KH84, LH14, LH32, LG02, FM76, FN82; Braasch, Joost 1971b: 59, LG40; Hubenov *et al.* 2000b**:** 319, FM97; Hubenov *et al.* 2000a**:** 343, KH74, LH14, LH22; Kumanski 1997: 26, GM02; Kumanski 2004: 237, LG40 .

Unpublished data: FN82, Dragalevska River, 23.3.1954; FN82, Vladayska River, 19.3.1954; FN71, Vitosha Mountain, Selimitsa hut, 31.05.1967, FM75, Blagoevgradska Bistritsa River, Blagoevgrad city (c.), 11.06.1970.

Rauser (1962) has described male adults of this Balkan endemic species, found by Dr. F. Balat on May 18, 1957 at the foot of Vitosha Mts. and Dr. P. Drenski on May 2, 1925 near Bankya. According to distributional data for Bulgaria, the species is typical for coarse gravel and stone ground, mixed with fine organic matter, branches and water sunk higher vegetation. *B. bulgarica* inhabits the subalpine and montane zones of Bulgarian rivers and it can be found in cold water with high ecological preferences (Table 1).

Brachyptera helenica Aubert 1956 (Fig. 3).

Literature records: Braasch, Joost 1971b: 59, NG48; Braasch, Joost 1971c: 108, NG48.

This species is also Balkan endemic. In contrast to the previous one, it prefers sandy substrate with micro- and macroalgae in the colline rivers (Ropotamo River).

Brachyptera risi (Morton 1896) (Fig. 4)

Literature records: Russev 1967: 91, KG77; Nachev 1982: 36, FM75; Sakelarieva *et al*. 2008: 207, FM85; Vidinova *et al*. 2008: 323, LG61.

Unpublished data: FN82, Vladayska River, 12.06.1966; LH32, Tundzha River, above Kalofer t., 20.06.1966, 28.02.1967; GM25, Mesta River, above Yakoruda t., 23.04.2005; FM83, Luda River, 23.04.2009.

Brachyptera risi is widespread especially at submontane and colline rivers in the epi-, meta- and

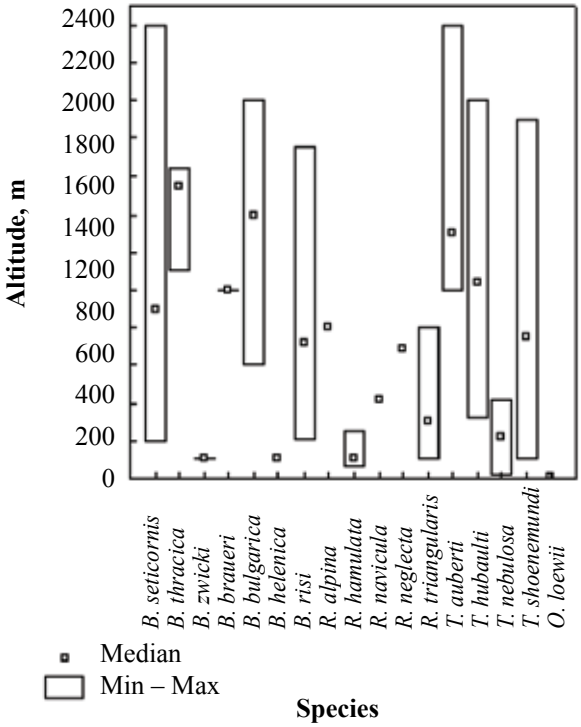

Fig. 1. A box plot of altitudinal range (median, min-max) of 17 Taeniopterygidae species in Bulgaria.

hyporhithral (even to 1750 m) (Table 2), but it is rarely found in the midcurrent of the rivers above 200 m (Fig. 1). It predominantly inhabits the rocky bottom (mesolithal) with woody debris, roots and logs (xylal) at S_R from 48.0 (β-mesosaprobity) to 84.72 (xenosaprobity). It is widespread in Blagoevgradska Bistritsa River.

Brachyptera seticornis (Klapálek 1902) (Fig. 4)

Literature records: *Taeniopteryx seticornis*: Navas 1929: 141, GM18; FN82; Buresch 1936: 146, FN82.

Brachyptera seticornis: Braasch, Joost 1971a: 269, KH84, LH14, LH32, LG02, KG 91, GM02, FM76, FN82; Braasch, Joost 1971b: 59, KH75, KH84; Braasch, Joost 1975: 165, LH02, KH82; Russev, Janeva 1975: 24, LG01, KG91, LG02; Nachev 1982: 36, FM75 ; Russev *et al*. 1984: 64, LH32; Janeva , Russev 1985: 20, LH32; Janeva 1987: 45, KH74, KH84, KH75; Janeva, Russev 1989: 6, FN91; Russev *et al*. 1991: 18, FP32; Hubenov *et al*. 2000b: 319, FM97; Hubenov *et al*. 2000a: 343, LH22; Vidinova *et al*. 2000: 54, GM13; Uzunov, Varadinova 2001: 57 FM73, FM72; Janeva , Bancheva 2002: 83, KH72; Sakelarieva *et al*. 2008: 207, FM85.

Unpublished data: FN91, Bistritsa River, 11.06.1967; FM85, Blagoevgradska Bistritsa River, Parangalitsa resort, 11.06.1970, 11.07.1990; LF29, Arda River, above Rudozem t., GM14, Votrachka River, 17.04.1990; GM14, Belichka River, above Belitsa v., 06.11.1990; Cherni Osam River, WPS 57, 04.04.1989, 1990; LH14, Cherni Osam River, above Cherni Osam v., 08.05.1991; KG91, Shirokolushka River, above Shiroka Luka v., WPS 477, 28.03.1993; KG80, Trigradska River, above Trigrad t., 28.03.1993; GM44, Sofan Dere River, 28.03.1993; KG54, Chepinska River, 28.03.1993; GM45, Ablanitsa River, 28.03.1993; KG50, Buynovska River, 28.03.1993; KG82, Devinska River, above Devin t., 30.04.1993; GM17, Musalenska Bistritsa River, 08.06.2000; GM03, Demyanitsa River, GM14, Glazna, 22.04.2005; GM31, Kanina River, below Ognyanovo v., 01.05.2005; FM82, Vlahinska River, 29.03.05; GM04, Razlozhka River, 21.04.2004, 30.03.2005; GM25, Mesta River, above Yakoruda v., 24.03.1993, 23.04.2005; GM22, Mesta River, Kupena, 22.04.2005; Momina Klisura, 31.03.2005; GM25, Cherna Mesta River, 23.04.2005; GM08, Beli Iskar River, Beli Iskar v., 25.02.2004, 02.05. 2004, 19.5.2005, 26.11.2005; FN90, Iskar River, Vedena, 02.05.2004; GM08, Cherni Iskar River, above Govedartsi v., 25.11.2004, 05.04.2005; GM19, Iskar River, Dragoshinovo v., 19.5.2005; FN90, Vedena River, 26.5.2005; KH75, Vit River, below Teteven t., 06.04.2005; KH75 – Beli Vit River, 06.04.2005; LH22, Stara Reka River, 29.05.2005; FN95, Prokopanik River, 28.3.2006, 28.4.2006; KG81, Vucha River, above Devin t., below Devin t., 12.10.2006, KG83, above Michalkovo v., below Michalkovo v., 4. 5. 2006; KG57, Yadenitsa River, 02.5.2006, 27.5.2007, 11.5.2008, 10.5.2009; GM35, Yundolska River, 02.5.2006, 27.5.2007, 11.5.2008, 10.5.2009; KG82, Devinska River, 13.5.2009; FM 83, Luda River, 23.4.2009, 16.5.2010.

Brachyptera seticornis is the most widespread Taeniopterigidae species. It dominates in Bulgarian Rivers during the colder months of the year. This rheophil species prefers xylal, micro-, meso -, and macrolithal river biocoenoses. We have found the species in three of the five saprobic zones (xenosaprobic, oligosaprobic and β-mesosaprobic). These fluctuations show a comparatively high ecological plasticity of this species.

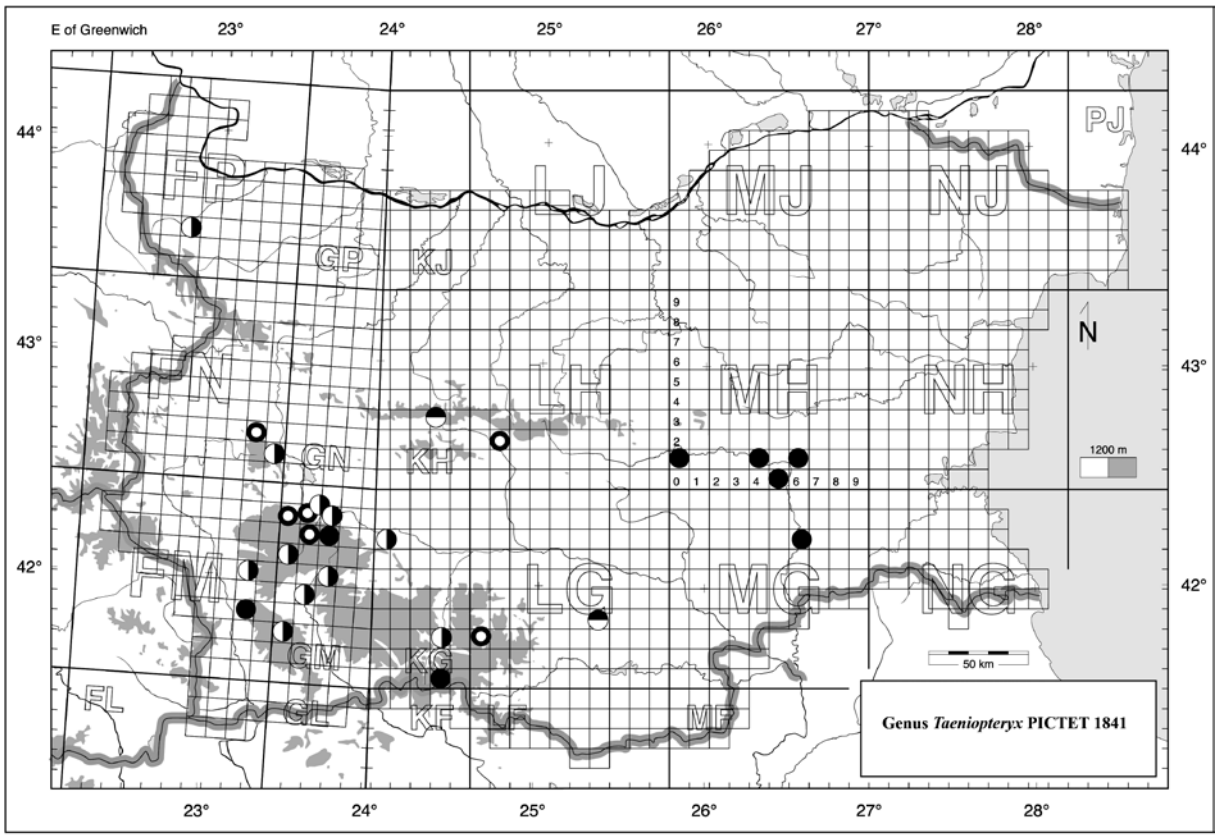

Fig. 2. Distribution of genus *Taeniopteryx* in Bulgaria: ○ – *T. auberti*, ◑ – *T. hubaulti*, ◓ – *T. nebulosa* and ● – *T. shoenemundi*.

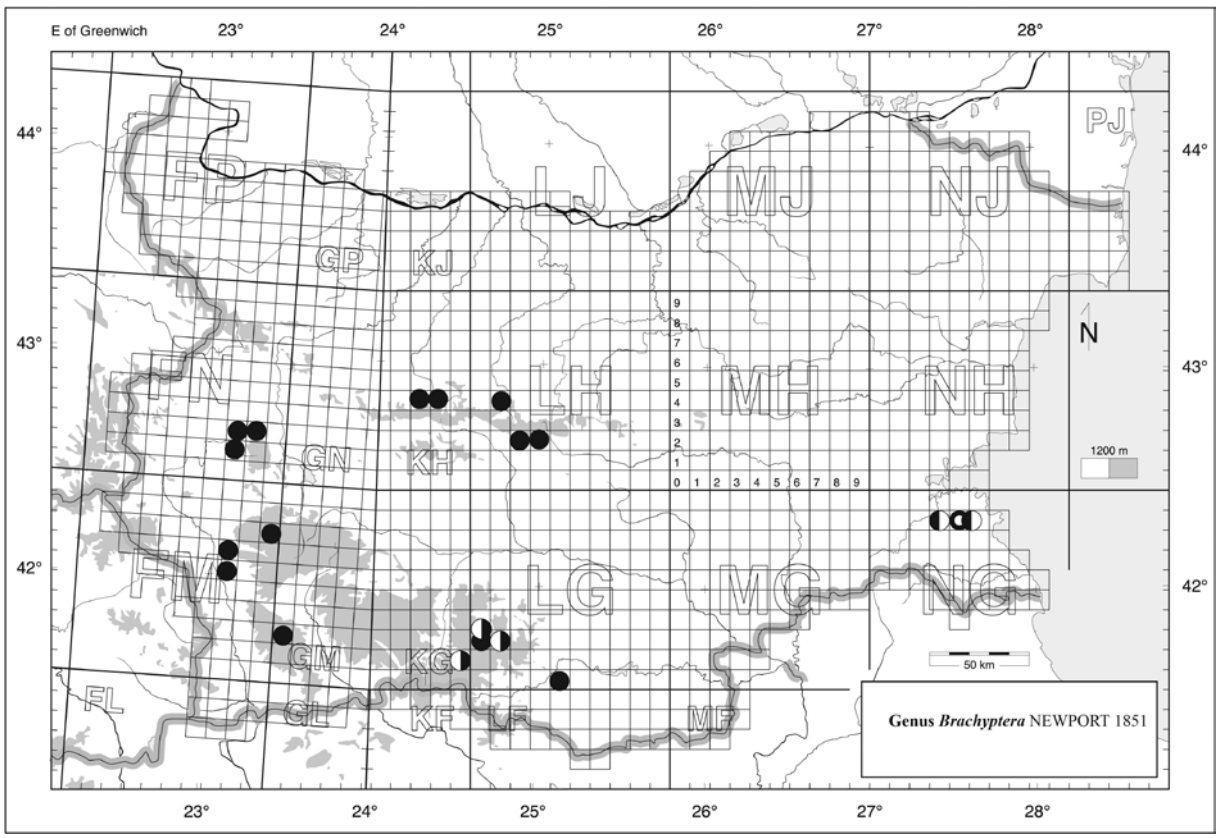

Fig. 3. Distribution of four species of the genus *Brachyptera* in Bulgaria: ● – *B. bulgarica*, ○ – *B. helenica*, ◐ – *B. zwicki* and ◑ – *B. thracica*.

Brachyptera thracica Rauser 1965 (Fig. 3)

Literature records: Rauser 1965: 126, LG12; Braasch, Joost 1971a: 269, LG02, KG91.

It is Bulgarian endemic species reported by Rauser (1965) and Braasch, Joost (1971a) from Rhodopes Mountains. The larva is unknown.

Brachyptera zwicki Braasch, Joost 1971 (Fig. 3)

Literature records: Braasch, Joost 1971c: 108, NG48; Braasch, Joost 1975: 165, NG38.

Like *B. helenica*, *B. zwicki* has similar requirements and inhabits the subzones of rhithral (Table 2, Fig. 1). Female, male adults and larvae are reported by Braasch, Joost (1971, 1975) from Strandzha Mountain.

Genus *Oemopteryx* Klapalek 1902

Oemopteryx loewii (Albarda 1889)

Literature records: Russev 1962: 117, MJ67; Russev 1966: 106, MJ67; Russev 1979: 325, MJ67.

Russev (1962) has reported the finding of *Oe. loewii* on March 18, 1955, from the Bulgarian stretch of Danube River at altitude 13 m (Table 1, Table 2, Fig. 1). It can be considered as extinct in the Bulgarian stretch of the river.

Genus *Rhabdiopteryx* Klapalek 1902

Rhabdiopteryx alpina Kühtreiber 1934 (Fig. 5)

Literature records: Braasch & Joost 1971a: 269, KH84; Gueorguiev *et al*. 1998: 174, KH84; Hubenov *et al*. 2000a**:** 343, KH74.

According to Vinçon, Murányi (2009), the geographic distribution of *R. alpina* covers the Alps. The authors consider the only Balkan record from Bulgaria (reported by Braasch, Joost 1971a) probably refers to *Rhabdiopteryx harperi* Vinçon, Murányi 2009.

Rhabdiopteryx hamulata (Klapalek 1902) (Fig. 5)

Literature records: Braasch, Joost 1975: 166, NG57, NG58, NG38; Gueorguiev *et al*. 1998: 174, NG57, NG58, NG38.

This species is known from Hungary, FYRMacedonia and Bulgaria (Kovacs, Muranyi 2008). *R. hamulata* as a component of the rheophile and limnophile biocoenose, inhabits gravel, cobbles, macrophytes and living parts of terrestrial plants of coline Bulgarian rivers.

Rhabdiopteryx navicula Theischinger 1974 (Fig. 5)

Literature records: Braasch, Joost 1975: 166, KH93; Gueorguiev *et al*. 1998: 174, KH93.

Braasch, Joost (1975) reported *R. navicula* from the submontane zone of Bulgaria. According to Tierno de Figueroa *et al*. (2010), it is cold stenothermal species and rheobiont. The larva of this species is unknown.

Rhabdiopteryx neglecta neglecta (Albarda 1889) (Fig. 5)

Literature records: Braasch, Joost 1971a: 269, FN88; Gueorguiev *et al*. 1998: 174, FN88.

Braasch, Joost (1971a) have reported the species *R. neglecta* from Botunya River (Stara Planina Range). It inhabits the montane zone, mainly in the epi -, and metarhithral of the river at 688 m (Table 2, Fig. 1).

Rhabdiopteryx triangularis Braasch, Joost 1972 (Fig. 5)

Literature records: Braasch, Joost 1972: 178, MH42, NG48; Braasch, Joost 1975: 166, NH54.

This rheobiont species is Balkan endemic. It is typical for meso-, and megalithal montane zones of Strandzha Mountain Rivers. The larva is unknown.

Statistical analyses

The results of CCA ordination (Fig. 6a) of 9 environmental variables (four substrate types, altitude, water temperature, pH, dissolved oxygen and oxygen saturation) and 7 species of Taeniopterygidae family (Table 1) showed that 46% of variance in species occurrences and abundance were accounted by the factors of all four canonical axes ($P = 0.004$). The first canonical axis is related to pH measurements and substrates (pelal, psammal and mesolithal), while the second canonical axis reflects five gradients: altitude, xylal, water temperature, dissolved oxygen and oxygen saturation. Stenothermal species (*T. nebulosa* and *Oe. loewii*) were with maximal abundance at lower temperature, but higher pH and substrate types (pelal and psammal). The species *T. hubaulti* and *B. seticornis* showed high correlation with higher altitude and xylal substrate. The dissolved oxygen and oxygen saturation explained most of the variance in the species composition of *T. shoenemundi* and *B. bulgarica*.

The results of ordination based on CCA of other nine environmental variables (water temperature, pH, dissolved oxygen, oxygen saturation, NO_2-N, NO_3-N, NH_4-N, PO_4-P and $KMnO_4$) and four species of Taeniopterygidae family are shown on Fig. 6b.

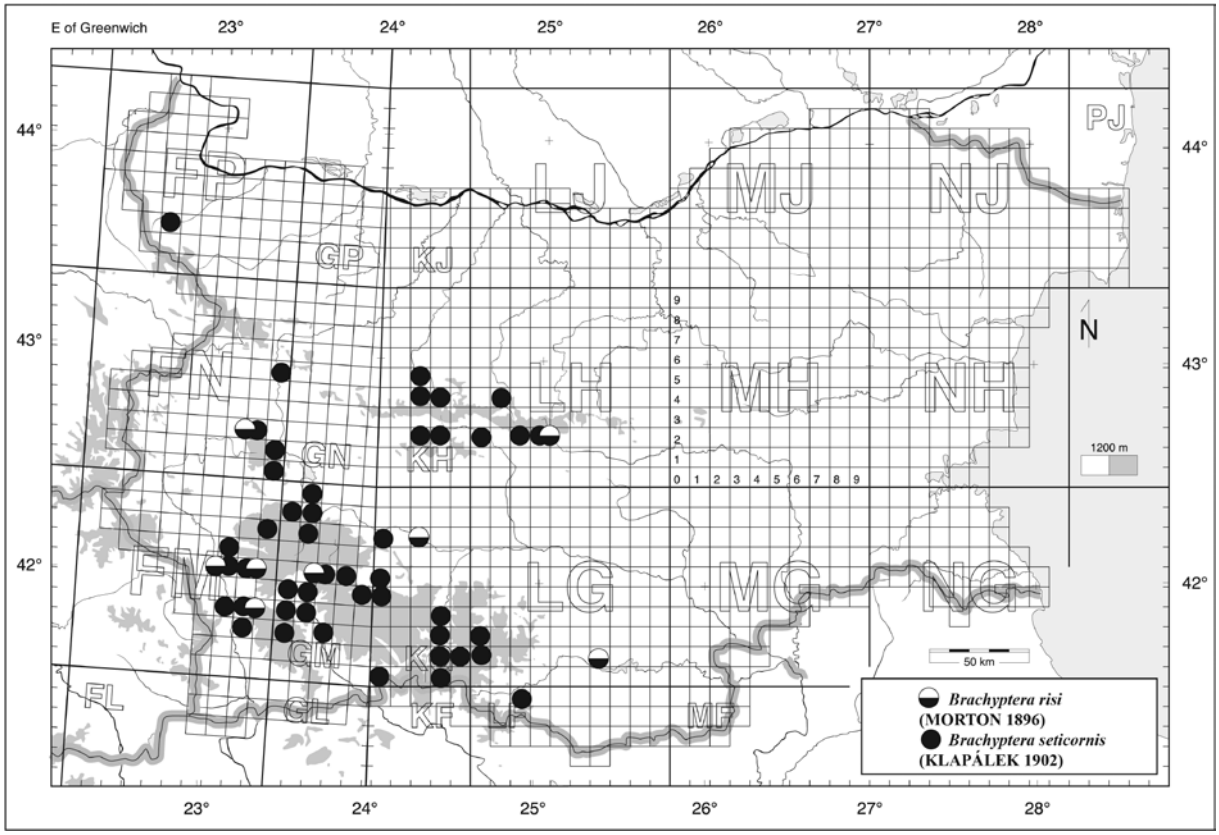

Fig. 4. Distribution of two species of the genus *Brachyptera* in Bulgaria: ◒ – *B. risi* and ● – *B. seticornis*.

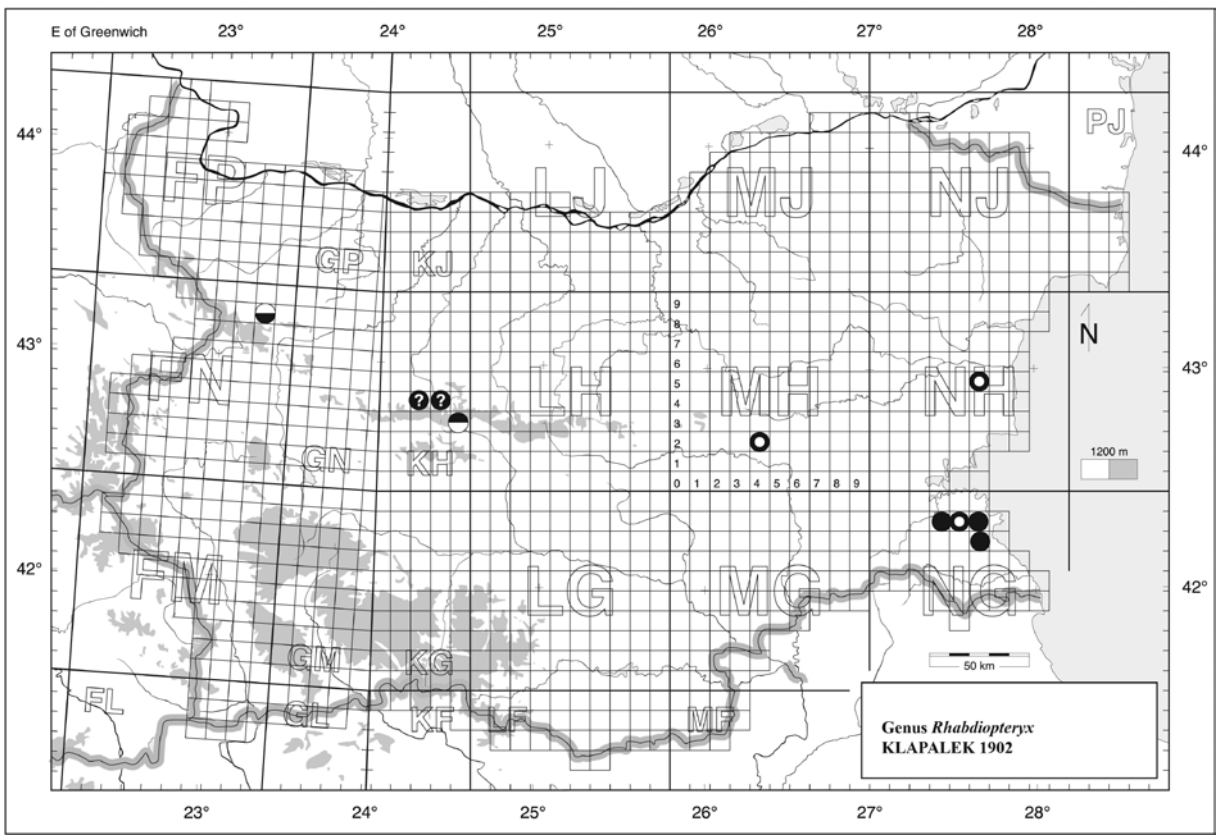

Fig. 5. Distribution of genus *Rhabdiopteryx* in Bulgaria: ? – *R. alpina*, ● – *R. hamulata*, ◓ – *R. navicula*, ◒ – *R. neglecta neglecta* and ○ – *R. triangularis*.

The eigenvalues and length of gradient of the all-canonical axes denote a good separation of the species along these axes. The variance explained by the all axes is 91.5 % and P = 0.006. Higher scores for axis 1 belonged to the stonefly species *T. shoenemundi*. The species *B. seticornis* and *B. risi* have the lowest score for axis 1 as they are with the lowest values of alkalinity, NO_2-N and NH_4-N. The same position toward axis 2 have the species *T. hubaulti*, *B. risi* and *B. seticornis* as they are with the lowest values of dissolved oxygen, oxygen saturation and NO_3-N. *T. hubaulti* has the highest score for axis 2 where the orthophosphate (PO_4-P) was higher and *B. risi* and *B. seticornis* have same position towards axis 2, where the permanganate oxidability ($KMnO_4$) and water temperature were higher.

The results of Spearman rank order correlation showed the same positive or negative significant ($P<0.05$) correlations between the species and environmental factors. *T. nebulosa* and *Oe. loewii* had positive correlations with pelal and psammal (both with $R_S = 0.69$) and negative with mesolithal ($r_S = -0.69$). *B. bulgarica* showed a negative relation with xylal ($r_S = -0.38$) and a positive one with dissolved oxygen ($r_S = 0.41$). *B. risi* correlated positively with xylal substrate ($r_S = 0.38$), but negatively with pH values ($r_S = -0.58$). *B. seticornis* had strong correlations with the altitude and xylal ($r_S = 0.55$ and $r_S = 0.69$, respectively). *T. hubaulti* and the altitude had a direct relation ($r_S = 0.36$). *T. shoenemundi* correlated with some environmental factors: positively with oxygen saturation ($r_S = 0.51$), NO_3-N ($r_S = 0.44$) and temperature ($r_S = 0.31$) and negatively with the altitude ($r_S = -0.54$) and xylal substrate ($r_S = -0.48$).

Discussion

According to Graf *et al*. (2009) 54 valid species from the above mentioned genera are currently known in Europe. Only 17 of them are reported for Bulgaria which represents about 15.74% from the total number of stonefly species (108). The geographical position of Bulgaria in the southeastern corner of the European continent, the complex of paleogeographic and paleoclimatic past as well as the presence of sufficient freshwater resources are the major significant factors favouring the existence of rich and original Plecoptera diversity. From a zoogeographical point of view, 4 species from the Taeniopterygidae, recorded in Bulgaria, are endemics: *Brachyptera thracica* is a Bulgarian endemic (only in the Rhodopes Mts.) and *B. bulgarica*, *B. helenica* and *Rhabdiopteryx triangulari* are Balkan endemics.

Based on the global categories and criteria of IUCN (2001, 2003, 2005), the taxa (species and subspecies) were classified into the following categories: extinct (EX); critically endangered (CR); endangered (EN); vulnerable (VU);

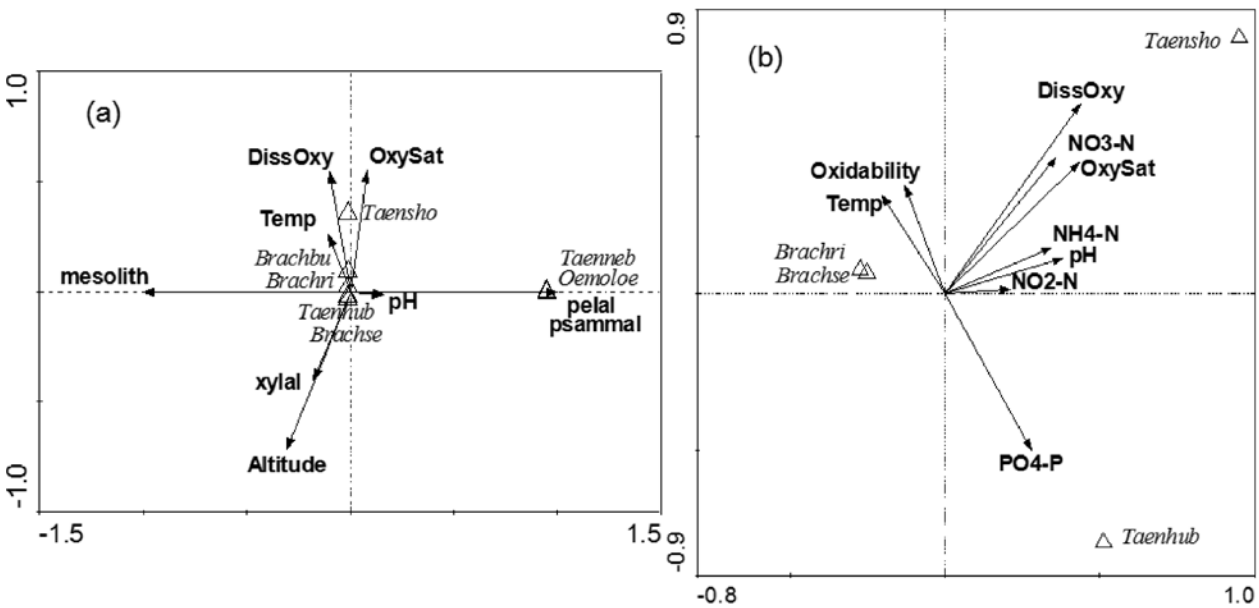

Fig. 6. CCA biplots of some environmental variables with 7 species (a) and 4 species (b). Statistical results: (a) ΣAllEV=5.0695; ΣCanEV=2.332, P=0.004; 1 axis=1.000, P=0.002; (b) ΣAllEV=2.022; ΣCanEV=1.850, P=0.006; 1 axis=0.886, P=0.098. For abbreviations of species names see in Table 1; Δ – response variables; → – explanatory variables.

nearly threatened (NT); least concern (LC); data deficient (DD); not evaluated (NE) (Golemansky V. (ed.) 2011). In the Red List of Threatened Invertebrates of Bulgaria, the stoneflies were not included. *Oe. loewii* had not been found since it was recorded by Russev (1962). It should be regarded as regionally extinct (RE). Nine species (*T. nebulosa, B. helenica, B. thracica, B. zwicki, R. alpina, R. hamulata, R. navicula, R. neglecta* and *R. triangularis*) were not observed during the last 40 years. Therefore, they should be included in the category critically endangered (CR). *B. bulgarica*, *T. auberti* and *T. hubaulti* should be regarded as endangered (EN) and *T. shoenemundi* – as vulnerable (VU). The species *B. risi,* and *B. seticornis* stand most frequently distributed in Bulgaria during the years and have not been threatened. Bulgarian occurrence of *B. braueri* species is doubtful.

T. auberti, T. hubaulti, B. bulgarica, B. thracica, R. alpina, R. navicula, R. neglecta and *R. triangularis* are stenoecic species and mainly inhabit epi- and metarhithral in montane brooks. They are found rarely, because of their high sensitivity to the environment parameters. Low temperature, considered as important factor for Plecoptera distribution, was found as significant factor only in distribution of *T. shoenemundi*. Most probably the climate change, driven to the increase of the temperature (in air and respectively in water bodies) during the last century and especially the last 10 years, is one of the reasons for adaptation or extinction of the species and due to this the correlations with water temperature are insignificant for the above species. According to Tierno de Figueroa *et al*. (2010) environmental impacts of increased water temperatures may include reduced habitats for cold-water aquatic species and oxygen depletion.

Both rhithral- and potamal- species *T. nebulosa, T. schoenemundi, B. helenica, B. zwicki* and *R. hamulata* can be found in submontane and coline river types. The species *O. loewii* that is restricted to potamal, already extinct from Bulgaria. According to Zwick (1992), all potamal species in Europe are either extinct or extremely vulnerable.

In Bulgaria Taeniopterygidae species were mainly found in waters with high dissolved oxygen and no stoneflies were observed in waters with dissolved oxygen under 7 $mg.L^{-1}$, 70% oxygen saturation and above 6 $mg.L^{-1}$ permanganate oxidability. Some species, such as *T. hubaulti* and *T. schoenemundi* were found in places, where watercourses contain alkaline water with a relatively high dH°.

According to Krno (2003) distribution of stoneflies is influenced mainly by physical and chemical variables and then by biological variables, mainly food. In addition, Mavri *et al.* (2000, 2003) and Ward, Stanford (1982) established that temperature and altitude are some of the considerable factors determining the distribution of the aquatic insects.

Our results confirm the above mentioned statements. The main environmental factors, which determine the species distribution and abundance of Taeniopterygidae family in Bulgarian rivers are substrate types, altitude, oxygen saturation and dissolved oxygen found by statistical analyses CCA and Spearman rank correlations.

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