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Recent Records and Ecological Notes on the Riffle Beetle *Potamophilus acuminatus* (Fabricius, 1792) (Coleoptera: Elmidae) in Serbia

Boris B. Novaković[1], Vanja M. Marković[2], Marija D. Ilić[2], Bojana P. Tubić[2], Jelena A. Đuknić[2], Ivana M. Živić[3]

[1] Serbian Environmental Protection Agency, Ministry of Agriculture and Environmental Protection, Ruže Jovanovića 27a, 11160 Belgrade; E-mail: boris.novakovic@sepa.gov.rs
[2] Institute for Biological Research "Siniša Stanković", University of Belgrade, Despota Stefana 142, 11060 Belgrade, Serbia; E-mail: vanjam@ibiss.bg.ac.rs
[3] Faculty of Biology, University of Belgrade, Studentski Trg 16, 11000 Belgrade, e-mail: ivanas@bio.bg.ac.rs

Abstract: *Potamophilus acuminatus* is regarded as a rare European riffle beetle, which is considered as endangered in many countries. The paper presents new data on the distribution and ecology of *P. acuminatus* in Serbia. During the Regular Annual Monitoring Sampling in the period 2011-2013, the presence of *P. acuminatus* was confirmed at eight sampling sites situated at six rivers: Lugomir, Ljudska Reka, Vlasina, Ibar, Zapadna Morava and Velika Morava. Particularly important are the records from the potamal zone of the Velika Morava River of this primarily hyporhitral and mesorhitral taxon. The specimens were found at the edges of stones, under broken tree trunks, rotting branches and stumps submerged in water. The species is absent in reservoirs, lakes and artificial water bodies in Serbia, as well as in lowland parts of the country (Vojvodina, Pannonian Plain). It is very rare and scarcely distributed in lowlands (except Pannonian Plain) and in river valleys in submountain regions. The rarity of findings and low number of the collected specimens are in accordance with literature data and previous records in Serbia. Recording *P. acuminatus* in the relatively polluted Velika Morava River suggests its somewhat broader ecological valence, particularly regarding tolerance to organic nutrients. This species, being more sensitive to pronounced negative human impacts on its aquatic habitats (larger lowland and submountain rivers) in this region, requires particular attention in future investigations.

Key words: *Potamophilus acuminatus,* Elmidae, distribution, habitat preferences, Serbia

Introduction

Potamophilus acuminatus (Fabricius, 1792), syn. *Parnus acuminatus* (Fabricius, 1792) (Elmidae) is the only representative of the riffle beetle subfamily Larainae in Europe (Kodada 1991, Jäch 2013). This beetle is a Palaearctic species with wide, but fragmented and localised distribution area, reaching from the Iberian Peninsula to Afghanistan, and from the Mediterranean Sea to the Baltic and North Seas. However, it is not confirmed in Scandinavia, Mediterranean islands, British Isles and Middle East/Asia Minor (Burakowski *et al*. 1983, Boukal *et al*. 2007, Ribera 2000, Gerend 2011). Recent discovery from northern Africa (Touaylia *et al.* 2010) proved that the species reaches farther to the south than it was demonstrated previously. Central Europe is considered as the centre of *P. acuminatus* distribution (Więźlak 1986).

Specimens of *P. acuminatus* are quite large, comparing to other elmids, with adults reaching 6.5 to 8.5 mm, and larvae 6.5 to 12 mm in length. The adult beetle is black-coloured and hairy, with reddish brown feet, claws and tentacles. Base of pronotum

deeply indented. Antennae long, 7 to 11-segmented; the first two segments longer than the succeeding segments (Olmi 1976, Visser, Van Zanten 2000). The most noticeable taxonomic character of larvae of *P acuminatus* is the presence of four dorsal ridges on thoracic and abdominal segments except on the last one (Olmi 1976). Pupation takes place inside the submerged wood in flowing waters, on which these xylophagous larvae feed and live (Visser, Van Zanten 2000).

In this paper, we present new findings of *P. acuminatus* in Serbia based on extensive field study in the period 2011-2013. This is an important contribution to the knowledge of recent distribution of this rare beetle in this part of South-Eastern Europe. Furthermore, data on habitat selection as well as other ecological preferences of this insufficiently studied species are provided.

Material and Methods

Macroinvertebrate benthological samples were collected as a part of the Regular Annual Water Quality Monitoring Program (RAWQMP), conducted by the Serbian Environmental Protection Agency (SEPA) and covering the entire territory of Serbia. Additional samples were provided as a part of the field research performed by the Institute for the Biological Research "Siniša Stanković" (IBRSS), mainly focused on the large rivers in Serbia. All sampling localities during our research in the period 2011-2013, are presented in Fig. 1. The presence/absence of *P. acuminatus* is marked.

The benthological samples were taken using either a standard benthological hand net (25 x 25 cm, 500 μm mesh size) or specimens were manually collected, following the multi-habitat sampling pro-

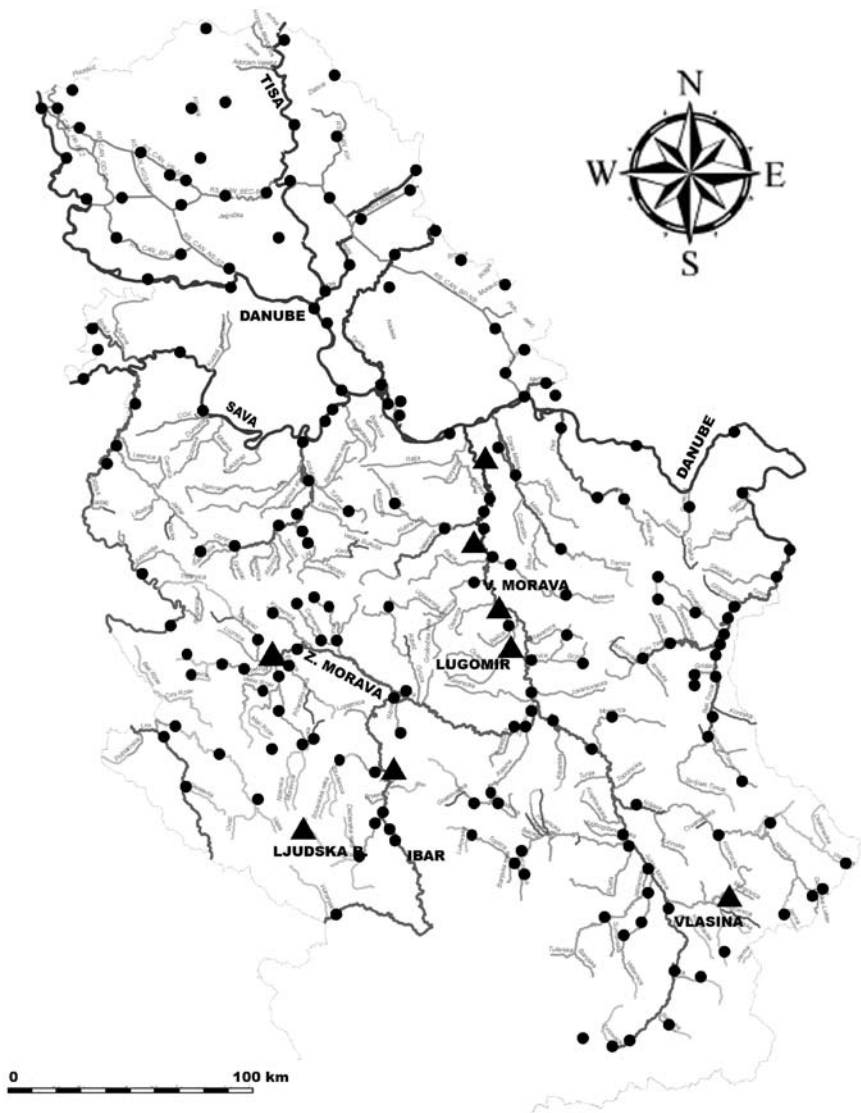

Fig. 1. Sampling sites on the territory of Serbia (2011-2013); triangle, presence of *P. acuminatus;* circle, absence of *P. acuminatus*

cedure (Hering *et al*. 2004). The samples were preserved using 70% ethanol and processed further in the laboratory. Identification of the species was done using stereomicroscopes Leica MS 5, Carl Zeiss Stemi 2000-C and adequate keys (Reitter 1908, Olmi 1976, Visser, Van Zanten 2000). Ecoregional classification (Table 3) was given according to Illies (1978).

Various physical and chemical parameters of the water were measured at most sites where benthological samples were taken (for mean annual values see Table 1). All measurements of these environmental factors were done with standardised apparatus and methods used by SEPA (Annual Water Quality Report 2011; 2012; 2013). Overall minimum, maximum and mean values of these parameters are shown in Table 2.

Results

During the extensive field study in the period 2011-2013, riffle beetle *Potamophilus acuminatus* was found in only eight samples, from eight sites, situated at six rivers: Lugomir, Ljudska Reka River, Vlasina, Ibar, Zapadna Morava and Velika Morava. An overview of the main data regarding the sites of finding is provided in Table 3. The species was found at an altitude range from 95 m (Markovac; Velika Morava River) to 586 m a.s.l. (Požega; Ljudska Reka River), and all finding sites except one (Vlasina; Ecoregion 7), were from Ecoregion 5 (Illies 1978).

Compared to over 800 samples taken during the sampling, the incidence of this species could be estimated to stands at only about 1%. Furthermore, the number of collected specimens was low, suggesting low population density. The highest number (five individuals) was recorded at the Gugaljski Most site (Zapadna Morava River), near the town of Požega (Western Serbia), in September 2011 (Table 3).

The species was found in oxygen rich waters (dissolved oxygen 10.56 mg/l, oxygen saturation 98.1%, on average; Table 2). Regarding organic nutrients in the water, *P. acuminatus* was found to tolerate NH_4^+ concentration as high as 4.52 mg l^{-1} (bad water quality; class V, according to Official Gazette of the RS 74/2011; Table 2). The lowest concentration of nitrates (NO_3^-) was 0.05 mg l^{-1} (Class I), and the highest was 2.1 mg l^{-1} (Class II). Obtained concentrations of orthophosphates (PO_4^{3-}) ranged from 0.01 mg l^{-1} (high water quality) to 0.207 mg l^{-1} (poor water quality). Values of Biochemical Oxygen Demand within a period of 5 days (BOD_5) at sites of *P. acuminatus* findings ranged from Class I to Class IV, according to Official Gazette of the Republic of Serbia 74/2011. A moderate tolerance to increased concentrations of total petroleum hydrocarbons was detected (at sites Majur/Lugomir and Ljubičevski Most/Velika Morava). Although present, total petroleum hydrocarbons products were not found in sufficient concentrations, to form a visible "layer" on the water surface or "coat" on the banks of rivers and lakes (Official Gazette of the RS 50/2012). We found that this beetle prefers slightly alkaline conditions (pH range from 7.5 to 8.9). The temperature range at the sites where the species was found varied from 0.3 ºC in winter to 27.8 ºC in summer. The obtained values of water turbidity ranged from 1.3 to even 1000 NTU. These high values of turbidity were primarily caused by heavy rains in the spring/autumn period. All measured values of conductivity at sampling sites where specimens were found, indicate high water quality (Class I; Official Gazette of the Republic of Serbia 50/2012), and ranged from 227 to 726 µS cm^{-1}. The values of total hardness of water ($CaCO_3$; 122-361 mg l^{-1}) at sites of *P. acuminatus* findings suggest that this species prefers hard waters (according to United States Geological Survey Scale).

Bearing in mind the Saprobic Index values (Zelinka, Marvan 1961; from Annual Water Quality Reports 2011-2013) it could be noted that this species primarily inhabits in Serbia relatively clear and unpolluted watercourses (good water quality; class II) which could be classified as β-mesosaprobic waters. However, we found that *P. acuminatus* could also tolerate moderate organic pollution, i.e. waters classified as α-mesosaprobic (moderate water quality; class III).

Discussion

Potamophilus acuminatus is considered a typical rheobiontic species which prefers well oxygenated waters, and is extremely sensitive to environmental degradation (Kodada 1991; Brasch 1995; Klausnitzer 1996; Jäch *et al*. 2005). Our results comply with some of these literature data, as the species was found in oxygen-rich waters. As a rheobiont with high oxygen demands, it is not unexpected that regarding longitudinal distribution of species along the watercourse, *P. acuminatus* is considered as hyporhitral taxon, which prefers lower parts of streams and brooks (Buczyński *et al*. 2011). Indeed, the majority of sites where this taxon was found (under boulders, large stones and rotting timbers submerged in water) during our study, belonged to mesorhitron and hyporhitron zone (Fig.1, Table 3). Some of these localities were situated in relatively unpolluted regions, surrounded by mountains and

Table 1. The mean annual values of measured physical and chemical parameters at sampling sites where *P. acuminatus* was recorded in Serbia (2011-2013)

RIVER	**Velika Morava**	**Velika Morava**	**Lugomir**	**Ljudska Reka**	**Vlasina**	**Zapadna Morava**	**Ibar**	**Velika Morava**
SITE	Markovac	Bagrdan	Majur	Požega	Vlasotince	Gugaljski Most	Ušće	Ljubičevski Most
Water temperature (°C)	12.573	12.436	14.844	15.400	13.691	12.720	11.592	12.975
Turbidity (NTU)	115.773	52.545	5.200	24.600	23.366	14.780	29.377	65.433
Total suspended solids (TSS) (mg l^{-1})	84.818	42.273	4.111	28.000	20.455	16.150	26.250	32.375
Dissolved oxygen (mg l^{-1})	10.427	10.582	10.589	9.600	10.855	10.760	10.697	10.063
% Oxygen Saturation	96.909	98.818	103.333	97.000	100.273	100.000	96.333	92.833
Alkalinity (mmol l^{-1})	3.927	3.736	5.900	3.400	2.673	3.470	3.776	3.403
Total hardness ($CaCO_3$) (mg l^{-1})	236.636	232.545	326.000	205.000	157.300	196.000	230.500	204.909
Bicarbonates (mg l^{-1})	237.091	227.909	343.000	196.000	146.455	205.700	218.833	209.167
pH	8.009	8.164	8.267	8.500	8.445	8.300	8.519	8.004
Conductivity (µS/cm)	453.182	413.364	619.222	364.000	275.455	365.700	486.750	393.000
Total dissolved solids (TDS) (mg l^{-1})	282.100	260.182	369.778	253.000	168.091	226.200	283.667	258.250
Ammonium ion (mg l^{-1})	0.625	0.162	0.697	0.003	0.023	0.205	0.221	0.194
Nitrites (mg l^{-1})	0.138	0.100	0.271	0.010	0.009	0.079	0.029	0.032
Nitrates (mg l^{-1})	0.736	0.836	0.812	0.600	0.234	0.970	1.208	0.842
Total nitrogen (mg l^{-1})	2.325	2.188	2.802	0.800	0.491	1.981	3.044	1.983
Orthophosphates (mg l^{-1})	0.122	0.106	0.063	0.058	0.038	0.079	0.120	0.062
Total phosphorus (mg l^{-1})	0.244	0.204	0.137	0.120	0.087	0.435	0.202	0.173
Sodium (mg l^{-1})	12.500	12.533	19.050	8.200	5.950	7.850	15.233	16.033
Potassium (mg l^{-1})	2.400	2.367	5.400	1.800	6.050	1.500	3.567	5.850
Chlorides (mg l^{-1})	11.782	11.291	15.111	6.000	3.182	8.370	14.158	14.167
Sulphates (mg l^{-1})	36.273	39.000	82.444	20.000	16.182	18.300	45.500	33.667
BOD_5 (mg l^{-1})	3.850	1.944	2.478	2.200	1.373	2.230	1.910	2.707
COD_{Mn} (mg l^{-1})	4.927	4.591	3.822	2.400	2.036	3.330	4.423	5.258
TOC (mg l^{-1})	5.710	4.522	6.400	2.500	2.267	3.814	4.463	5.083

Table 2. The minimum, the maximum and the mean values of measured physical and chemical parameters from *P. acuminatus* localities in Serbia (2011-2013); „*“ indicates the median as central tendency measure

PARAMETER	Minimum	Maximum	Mean/Median
Water temperature (ºC)	0.300	27.800	12.912
Turbidity (NTU)	1.300	1000.000	10.300*
Total suspended solids (TSS) (mg l^{-1})	0.500	539.000	11.500*
Dissolved oxygen (mg l^{-1})	5.300	14.700	10.559
% Oxygen saturation	59.000	166.000	98.105
Alkalinity (mmol l^{-1})	1.900	6.600	3.785
Total hardness ($CaCO_3$) (mg l^{-1})	122.000	361.000	224.973
Bicarbonates (mg l^{-1})	89.000	384.000	223.763
pH	7.500	8.900	8.235
Conductivity (µS cm^{-1})	227.000	726.000	425.645
Total dissolved solids (TDS) (mg l^{-1})	100.000	440.000	261.667
Ammonium ion (mg l^{-1})	0.005	4.520	0.110*
Nitrites (mg l^{-1})	0.003	0.970	0.035*
Nitrates (mg l^{-1})	0.050	2.100	0.809
Total nitrogen (mg l^{-1})	0.400	5.900	2.139
Orthophosphates (mg l^{-1})	0.010	0.207	0.085
Total phosphorus (mg l^{-1})	0.015	1.685	0.157*
Sodium (mg l^{-1})	3.100	35.900	13.033
Potassium (mg l^{-1})	0.900	12.500	3.911
Chlorides (mg l^{-1})	0.500	26.000	11.163
Sulphates (mg l^{-1})	11.000	210.000	37.908
BOD_5 (mg l^{-1})	0.600	9.000	2.334
COD_{Mn} (mg l^{-1})	1.600	10.100	4.092
TOC (mg l^{-1})	1.700	10.400	4.710
Total petroleum hydrocarbons (mg l^{-1})	0.000	0.050	0.011
Phenol Index (mg l^{-1})	0.000	0.016	0.001*

preserved forests, although near human settlements or even towns. Such localities were Požega at the Ljudska Reka River, Vlasotince at the Vlasina River, Majur at the Lugomir River, Ušće at the mouth of the Studenica River with the Ibar and the Gugaljski Most (the Gugalj Bridge) near the confluence of the Moravica and Đetinja Rivers. Having in the ecology and distribution of this rare taxon, it should be noted that we found it in relatively degraded and polluted habitats in the potamal type of river (three sites along the Velika Morava River; Fig. 1, Table 3). The Velika Morava River is situated in densely populated and polluted region “Pomoravlje”, in central Serbia (Kolarević *et al.* 2012; Marković *et al.* 2015). Moreover, the sites at the Velika Morava River (Ljubičevski Most, Markovac and Bagrdan) were characterised by modified gravel banks and a few small input canals, and this river could be regarded as canalised, heavily modified water bodies. Due to the findings of a few more rare taxa at this river in recent years (Marković *et al.* 2014, Marković *et al.* 2015) the Velika Morava River, despite all negative anthropogenic impacts, still could be considered as refugium for rare macroinvertebrate taxa in Serbia. Because of this, it is imperative to improve and to protect aquatic habitats along the river.

Although considered a sensitive taxon in the literature, in our field research *P. acuminatus* was found in some polluted and degraded habitats, as well. According to our data, it can tolerate poor and even bad water quality (based on the obtained values of NH_4^+, PO_4^{3-} and BOD_5). Considering saprobic preferences (Zelinka, Marvan 1961) also could be stated that this species, although primarily inhabitant of unpolluted or slightly polluted waters (β-mesosaprobic taxon), could as well tolerate moderate organic pollution (α-mesosaprobic taxon). These findings suggest somewhat broader ecological valence of this beetle than previously stated in the literature.

The withdrawal of *P. acuminatus* in Europe is mainly explained by its sensitivity and the degradation, fragmentation and overall habitat loss (Klausnitzer 1996; Ribera 2000). Moreover, habitat fragmentation is considered as one of the key factors

Table 3. The main data regarding sites in Serbia where *P. acuminatus* was recorded during our research in 2011-2013; „*“ indicates the larval findings

River	Site	GPS Coordinates	Elevation (m)	Sampling Date	Number of specimens	Catchment	Ecoregion (Illies, 1978)
Lugomir	Majur	43° 56’ 40” 21° 16’ 49”	131	2 June 2011	3	Velika Morava	5
Ljudska Reka	Požega	43° 09’ 41” 20° 24’ 23”	586	17 June 2011	1	Raška-Ibar	5
Vlasina	Vlasotince	42° 58’ 00” 22° 08’ 12”	265	9 Sep 2011	1	Južna Morava	7
Zapadna Morava	Gugaljski Most	43° 52’ 06” 20° 06’ 40”	319	17 Sep 2011	5	Velika Morava	5
Ibar	Ušće	43° 27’ 54” 20° 37’ 36”	347	18 June 2012	2	Zapadna Morava-Velika Morava	5
Velika Morava	Markovac	44° 13’ 29” 21° 09’ 14”	95	18 Jan 2011	2*	Velika Morava	5
Velika Morava	Bagrdan	44° 05’ 13” 21° 11’ 23”	102	18 Jan 2011	1*	Velika Morava	5
Velika Morava	Ljubičevski Most	44° 35’ 12” 21° 08’ 18”	127	29 June 2012	4	Velika Morava	5

limiting the dispersion of this species (Boukal *et al.* 2007). Knowing that adults of this elmid beetle could be regularly found in land environment, as the only Middle-European elmid with this characteristic (Jäch *et al.* 2005), habitat fragmentation should not be the main reason for its scarce findings. Indeed, some data imply that dispersal occurs despite fragmentation (Buczyński, Pałka 2003). During our research, fragmented areal of *P. acuminatus* in Serbia could be assumed, due to rarity of findings and spatial distance between them. Only the Velika Morava could be considered as a river with relatively continuous, unfragmented habitats of this rare elmid species in Serbia.

If we suppose somewhat lesser sensitivity of this species, according to our data based mostly on the adults, then as one of the main reasons for its rarity could be its obligatory water stage - larvae. The literature states that specific threat for this taxon is associated with trophic requirements of its larvae (xylophagous), so even the "positive" activities, such as water "care" (removal of decaying wood), could result in the total vanishing of the species from the area (Jäch *et al.* 2005).

Central Europe was considered as the centre of *P. acuminatus* distribution (Więźlak 1986). However, due to decreasing population trends in many of the Central European countries, e.g. Germany, the Czech Republic and Austria (Klausnitzer 1996, Jäch *et al.* 2005, Boukal *et al.* 2007), nowadays the area of Hungary remains the main centre of distribution and refugium for this species (Kovács *et al.* 1999, Jäch *et al.* 2005, Kovács, Merkl 2005, Kálmán *et al.* 2009, Csabai *et al.* 2010). Relatively dense populations of *P. acuminatus* (larvae) were recorded in Eastern Romania (Lower Prut Floodplain Natural Park) (Costea *et al.* 2013). The authors supposed the possibility of more prominent presence of this species in Romania, due to numerous suitable habitats still existing in medium to large natural Romanian rivers. Our findings suggest similar situation in Serbia, as well. The presence of many well-preserved, natural rivers harbours many potential habitats for *P. acuminatus*. Besides, the species is present in some degraded and moderately polluted rivers, such as the Velika Morava, as well. The Velika Morava River, due the frequency of *P. acuminatus* records, could be considered as a corridor for this species, which links the Hungarian Plain (as the centre of its diversity) and the Central Balkans, with many potential habitats.

Potamophilus acuminatus together with other species of the family Elmidae, *Macronychus quadrituberculatus* and *Stenelmis canaliculata*, are among the most vulnerable riffle beetle species in Serbia (Novaković, Mesaroš 2014, Novaković, unpublished

data). Considering the species habitat preference, it is found that *P. acuminatus* predominantly inhabits stretches of watercourses with fast water flow, usually at the edges of stones, broken tree trunks, rotting branches and stumps submerged in water. In Serbia *P. acuminatus* was found to be rare riffle beetle species, scarcely distributed in lowlands (except the Pannonian Plain) and in river valleys in submountain regions. Besides, the species is absent from reservoirs, lakes and artificial water bodies in Serbia, as well as in the lower part of the country (Vojvodina, Pannonian Plain). Its larva tolerates moderate organic pollution, while it prefers higher oxygen content. One of crucial factors for its presence is the presence of wood debris in the water, which was recorded at all sampling sites where this species was found in Serbia. This is expected as larvae are obligatory xylophagous: they feed on dead, partially decomposed wood submerged in water, preferring branches and logs of diameter of ca. 8 cm (Klausnitzer 1996, Hoffman, Hering 2000, Jäch *et al*. 2005).

P. acuminatus is regarded as valuable and threatened aquatic insect (Klausnitzer 1996, Graf , Kovács 2002). Due to its rarity and low numbers of collected specimens, which could indicate the threat of extinction (Pawłowski *et al*. 2002), in many countries *P. acuminatus* is regarded as an endangered species. Furthermore, in Austria, the Czech Republic, Germany and Slovakia it has been assessed as CR (critically endangered) taxon (Geiser 1998, Holecová, Franc 2001, Boukal 2005, Jäch *et al*. 2005). The decline of this species in Europe is likely a consequence of general degradation of suitable habitats, to which *P. acuminatus* is extremely sensitive (Braasch 1995). Fragmentation of habitats is highlighted as particularly dangerous (Ribera 2000, Boukal *et al.* 2007). Ironically, even "water care" could lead to disappearance of this beetle, if it includes removing decaying wood, a primary food source and a habitat for its larval development (Jäch *et al*. 2005). Having in mind these facts it is not surprising that some authors (Ribera 2000, Jäch *et al*. 2005) proposed that *P. acuminatus* should be included to the Red List of IUCN as vulnerable species (VU). Our findings contribute to the overall knowledge of this taxon. In Serbia, despite many potential habitats, this beetle is rare, and found in low densities when present, which is in accordance with literature data on its sensitivity and rarity. Comparison with literature data regarding previous findings (SIMIĆ *et al* 2006, Paunović *et al* 2010) confirms its rarity. On the contrary, the rarity of findings could reflect the lack of optimal habitats for this riffle beetle species.

However, its presence in some degraded and polluted habitats, although in very low number, such as along the Velika Morava River, suggests somewhat broader ecological tolerance of this rare species. Future investigations should shed more light on the presence of this taxon in the region and on its ecological preferences and sensitivity.

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