First results of a faunistic survey on the Orthoptera of Jadovnik Mountain, southwestern Serbia, with data on the calling songs of some bush cricket species

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Abstract: During field trips conducted in 2015 and 2016 at 22 different localities on Jadovnik Mountain, 68 species were recorded. The calling songs of 4 species were studied in detail, and a new song type of Isophya clara was described. Metrioptera brachyptera and Locusta migratoria are rerecorded for the first time in 40 years for the Serbian fauna.

Key words: Serbia, Jadovnik, Sopotnica Waterfalls, bioacoustics, Isophya clara, Locusta migratoria

Jadovnik Mountain is located in southwestern Serbia, on the western edge of Pešter plateau, between Prijepolje and Sjenica, near the border of Montenegro. Triassic sandstones and limestones form this 12-km long mountain with its highest peak being Katunić (elevation 1734 m a.s.l.; Marković, 1990). The high parts are covered with meadows and pastures, while the slopes are covered with dense beech and spruce forests. Jadovnik is best known for Sopotnica Waterfalls, which in 2005 was proclaimed a Natural Monument.

Until now, no faunistic study about Orthoptera has been conducted on this mountain. There is only very limited information available about the Orthoptera fauna of western Serbia (e.g., in Brunner von Wattenwyl, 1882; Pančić, 1883; Grebenščikov, 1950; Stevanović, 1953; Adamović, 1970; Adamović, 1975; Pavičević and Karaman, 2001; Ingrisch and Pavičević, 2010; Karaman et al., 2011; Pavičević et al., 2014) However, there are detailed studies for neighboring areas in Montenegro indicating a high diversity in Orthoptera (Ingrisch and Pavičević, 2012). In Serbia, 182 species have been recorded so far (Pavičević et al., 2014; Ivković et al., 2015; Pavičević and Ivković, 2015; Iorgu et al., 2016). The aim of this paper is to present data on the Orthoptera of Jadovnik Mountain, together with new information about ecology and songs of species that have been recently described and are little known in Serbia.

This research was conducted in 2 periods, during 9–14 July 2015 and 16–23 July 2016. In the first year observations were performed mostly in the area of Sopotnica Waterfalls Natural Monument, while in the second year this research was expanded to other localities of Jadovnik Mountain. Specimens were obtained by net sweeping of herb and shrub vegetation, beating from trees and shrubs, individual collection of specimens, and night collecting using a headlamp. In addition, collecting using pitfall traps was conducted. Localities where material was collected/observed are represented in the Table.

Material was usually identified in the field. For more detailed analysis, Poecilimon, Isophya, Barbitistes, and Metrioptera males were taken alive to the laboratory where their calling song was recorded. Prepared specimens in 96% ethanol are deposited in the author's private collection.

Images of species and habitats were taken with Sony A58 digital SLR camera equipped with a Tamron SP AF 90 mm f/2.8 Di Macro lens. Image editing was done using SilkyPix Developer Studio Pro 6 and Adobe Photoshop software. Stridulatory files were studied with a scanning electron microscope (JEOL JSM 6460 LV) at the UCEM–NS (University Centre for Electron Microscopy, Novi Sad).

Audio recordings were taken with a Roland R-05 digital audio recorder (microphone frequency response of 0.02–40 kHz; sampling rate of 96 kHz). Sound analysis and figures of the oscillograms were prepared using Adobe Audio CC 2015 software and Cool Edit Pro 2.1. All analyzed recordings in this paper were uploaded to the Orthoptera Species File website (Eades et al., 2016).

For the song terminology, Heller et al. (2004) was used. Calling song: song produced by an isolated male. Functional unit of the song: the smallest part of the song, which contains all necessary song elements in the appropriate order to elicit female response. Syllable: the sound produced by one complete up (opening) and
down (closing) stroke of the forewings. Impulse: a simple, undivided, transient train of sound waves. After-click: click produced with considerable delay after the main impulse group.

Specimens were identified using the following main literature sources: Ramme (1951), Harz (1969, 1975), Willemse et al. (2009), Iorgu and Iorgu (2008), Ingrisch and Pavićević (2012), and Sardet et al. (2015). Classification is based on the Orthoptera Species File Online, v.5.0/5.0 (Eades et al., 2016).

**List of species**

**Ensifera**

Phaneropteridae Burmeister, 1838

Phaneropterinae Burmeister, 1838

*Phaneroptera* Servelle, 1831


ECOLOGY: Herbicole.


ECOLOGY: Arbusticole–arboricole.

*Isophya* Brunner von Wattenwyl, 1878


ECOLOGY: Pratinicole; herbicole.

4. *Isophya modestior* Brunner von Wattenwyl, 1882: 2♂♂, Sopotnica Waterfalls (4), 10.07.2015; 1♂, same

### Table. List of localities where the material was collected.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Coordinates</th>
<th>Altitude (m)</th>
<th>Description of habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sopotnica Ra</td>
<td>43.307, 19.733</td>
<td>960</td>
<td>pasture with <em>Robina pseudoacacia</em> trees near the road</td>
</tr>
<tr>
<td>2 Sopotnica (meadow)</td>
<td>43.306, 19.738</td>
<td>1000</td>
<td>mesophilous meadow with small stream</td>
</tr>
<tr>
<td>3 Sopotnica Co</td>
<td>43.305, 19.737</td>
<td>970</td>
<td>pasture with <em>Corylus</em> trees on the edge</td>
</tr>
<tr>
<td>4 Sopotnica Waterfalls</td>
<td>43.302, 19.739</td>
<td>960</td>
<td>pasture that is heavily grazed by sheep. On the upper part with <em>Juniperus</em> trees.</td>
</tr>
<tr>
<td>5 Sopotnica (forest meadow)</td>
<td>43.297, 19.735</td>
<td>850</td>
<td>forest meadow</td>
</tr>
<tr>
<td>6 Čelina</td>
<td>43.292, 19.734</td>
<td>995</td>
<td>roadside in the forest with small parts with low grass</td>
</tr>
<tr>
<td>7 Čelina (forest edge)</td>
<td>43.289, 19.734</td>
<td>1075</td>
<td>forest edge, on upper parts mesophilous meadow</td>
</tr>
<tr>
<td>8 Čelina (roadside)</td>
<td>43.288, 19.736</td>
<td>1125</td>
<td>roadside surrounded with bushes and low vegetation</td>
</tr>
<tr>
<td>9 Vodice</td>
<td>43.280, 19.745</td>
<td>1150</td>
<td>heavily grazed pasture with rocks, eastern part is lower mesophilous meadow</td>
</tr>
<tr>
<td>10 Vodice (roadside)</td>
<td>43.280, 19.747</td>
<td>1155</td>
<td>roadside with small bushes and rocks</td>
</tr>
<tr>
<td>11 Sopotnica (hiking trail)</td>
<td>43.308, 19.739</td>
<td>1040</td>
<td>hiking trail with stones</td>
</tr>
<tr>
<td>12 V. Rastovac</td>
<td>43.310, 19.743</td>
<td>1150</td>
<td>mesophilous meadow</td>
</tr>
<tr>
<td>13 Ogoreljača</td>
<td>43.311, 19.752</td>
<td>1310</td>
<td>forest glade with <em>Rubus</em> sp.</td>
</tr>
<tr>
<td>14 Ogoreljača–Mali Jadovnik (meadow)</td>
<td>43.307, 19.763</td>
<td>1460</td>
<td>mesophilous meadow in spruce forest</td>
</tr>
<tr>
<td>15 Ogoreljača–Mali Jadovnik (roadside)</td>
<td>43.308, 19.767</td>
<td>1490</td>
<td>roadside surrounded with mesophilous meadows</td>
</tr>
<tr>
<td>16 Mali Jadovnik (roadside)</td>
<td>43.306, 19.772</td>
<td>1520</td>
<td>roadside surrounded with mesophilous meadows</td>
</tr>
<tr>
<td>17 Mali Jadovnik (meadow)</td>
<td>43.299, 19.785</td>
<td>1540</td>
<td>mesophilous meadow with <em>Juniperus</em> and rocks</td>
</tr>
<tr>
<td>18 Mali Jadovnik–forest roadside</td>
<td>43.302, 19.794</td>
<td>1510</td>
<td>forest roadside</td>
</tr>
<tr>
<td>19 Derventa</td>
<td>43.305, 19.803</td>
<td>1250</td>
<td>mesophilous meadows</td>
</tr>
<tr>
<td>20 Gvozd</td>
<td>43.320, 19.783</td>
<td>1142</td>
<td>mesophilous meadows</td>
</tr>
<tr>
<td>21 Kobilja Glava</td>
<td>43.326, 19.779</td>
<td>1270</td>
<td>forest roadside</td>
</tr>
<tr>
<td>22 Divljaci</td>
<td>43.323, 19.744</td>
<td>1055</td>
<td>mesophilous meadows</td>
</tr>
</tbody>
</table>

ECOLOGY: Herbicole.

ECOLOGY: Pratinicole; herbicole.

5. *Isophya clara* Ingrisch & Pavićević, 2010 (Figure 1): 2♂♂, 1♀, Gvozd (20), 12.07.2015; 2♂♂, 3♀♀, same locality 20.07.2016; 2♂♂, Kobilja Glava (21), 20.07.2016; 2♂♂, Divljaci (22), 20.07.2016.

ECOLOGY: Pratinicole; herbicole.

Remarks: *I. clara* was found in large numbers, mostly in mesophilous meadows. In the locality Gvozd (20) in 2015, this species was detected in mesophilous meadow, but in 2016 the same locality had been mowed and so most animals were found in higher and drier meadows. Males began to sing in the afternoon and they sang until dark. Ingrisch and Pavićević (2010) wrote that the song of *I. clara* consists of single, decrescending syllables with 20–31 impulses each without after-clicks. In song recordings of 2 males from Jadovnik Mountain (Gvozd), syllables with after-clicks (n 6) were detected (impulse number of main group 24–29: n = 26; 29 °C; Figure 2). A similar syllable structure (Figure 3) was recorded in a population from Ovčar-Kablar Gorge (western Serbia). In both populations, the songs were formed of series of syllables (3–9). Syllables in specimens from Gvozd consisted of a main part of 200–306 ms and after-clicks with a total duration of 570–585 ms, with intervals between them of 1–1.5 s. In a specimen from Ovčar-Kablar Gorge, the song consisted of main part of 212–286 ms and after-clicks with a total duration of 467–539 ms, with intervals between syllables of 0.877–1.886 s.

Stridulatory files of specimens from both populations show a different number of teeth than those published by Ingrisch and Pavićević (2010) (58–72). Specimens from Gvozd have 74 teeth (Figure 4A), while a specimen from Ovčar-Kablar Gorge has 49 teeth (Figure 4B).

**Barbitistes** Charpentier, 1825


ECOLOGY: Silvicole; arbusticole–arboricole.


**Leptophyes** Fieber, 1853


ECOLOGY: Pratinicole.


ECOLOGY: Silvicole; arbusticole.

**Poecilimon** Fischer, 1853

![Figure 1. Isophya clara (male).](image1)

![Figure 2. Isophya clara, oscillograms of male calling song from Gvozd. A) 6 syllables; B) syllable with after-click.](image2)

ECOLOGY: Pratinicole; herbicole–arbusticole.

Remarks: *P. affinis dinaricus* was found in moist forest meadow (Figure 6).

In the first year of observation, only *E. brachyptera* was found together with this species, while in 2016 a large population of *P. pseudornatus* was also found together with *P. affinis dinaricus*, as well as a few *M. brachyptera* on the edge of the meadow. Specimens were found by their song, which they produced only during daytime, while males were singing day and night in captivity. Recorded song of 1 male (n 27, 20 °C) consists of single syllables (Figure 7A) lasting 64–81 ms with intervals between them of 5–15 s. Songs of 2 males (n 8, 28 °C) also consist of single syllables (Figure 7B) lasting 64–68 ms, with intervals between them of 5.5–11.5 s.

Stridulatory file has 153 teeth (Figure 4C). This observation represents the second locality in Serbia for this species, as there were only 2 data in the literature that referred to Kamena Gora (Ingrisch and Pavićević, 2010; Pavićević et al., 2014).

11. *Poecilimon pseudornatus* Ingrisch and Pavićević, 2010 (Figure 9): 7♂♂, 4♀♀, Sopotnica Ra (1), 10.07.2015; 10♂♂, 6♀♀, same locality, 22.07.2016; 3♂♂, 3♀♀, Sopotnica (meadow) (2), 09.07.2015; 4♂♂,
Figure 5. *Poecilimon affinis dinaricus* (male).

Figure 6. Locality: Ogoreljača–Mali Jadovnik (meadow).

Figure 7. Calling song of *Poecilimon affinis dinaricus* males from Ogoreljača–Mali Jadovnik (meadow). Syllables at different temperatures: A) syllable at 20 °C; B) syllable at 28 °C.

Figure 8. SEM image of the stridulatory file in *Poecilimon affinis dinaricus*, Ogoreljača–Mali Jadovnik (meadow).

Figure 9. *Poecilimon pseudornatus* (male).

ECOLOGY: Pratinicole–silvicole; herbicole–arbusticole.

Remarks: Poecilimon pseudornatus was the most common species on Jadovnik Mountain. Specimens were found mostly in mesophilous meadows, where they were singing and walking (similar to P. denticauda) or sitting on Rubus bushes. Males were singing throughout the day until late in the night (observed in specimens around the mountain lodge). Song was recorded from 2 different populations—Sopotnica Ra and Ogoreljača–Mali Jadovnik (roadside). Song in both males consisted of single, loud syllables (Figures 10A and 10B), lasting 300–331 ms with intervals between 3.5–4 s in Sopotnica Ra (n 16, 28 °C), and 284–309 ms with intervals between 4.5–6.5 s in Ogoreljača–Mali Jadovnik (roadside) (n 11, 28 °C).

A male from Sopotnica Ra has 252 stridulatory teeth (Figure 11A); another from Ogoreljača–Mali Jadovnik (roadside), 225 (Figure 11B).


ECOLOGY: Pratinicole–silvicole; herbicole–arbusticole.


ECOLOGY: Pratinicole; herbicole.


ECOLOGY: Pratinicole; herbicole.


ECOLOGY: Pratinicole; graminicole. Tettigoniidae Krauss, 1902


ECOLOGY: Silvicole; arboricole.

Conocephalinae Burmeister, 1838

Conocephalus Thunberg, 1815
ECOLOGY: Pratinicole.  
*Ruspolia* Schulthess, 1898

ECOLOGY: Pratinicole.

ECOLOGY: Pratinicole; graminicole–arboricole.  
*Decticus* Serville, 1831

ECOLOGY: Pratinicole; terricole–herbicole.  
*Platycleis* Fieber, 1853

ECOLOGY: Pratinicole; graminicole.  
*Roeseliana* Zeuner, 1941

ECOLOGY: Pratinicole; graminicole–herbicole.  
*Metrioptera* Zeuner, 1941

23. *Metrioptera brachyptera* (Linnaeus, 1761) (Figure 12): 3♂♂ (2 nymphs), 1♀ (nymph), Ogreljača–Mali Jadovnik (meadow) (14), 20.07.2016.  
ECOLOGY: Pratinicole; graminicole.  
Remarks: Most *M. brachyptera* specimens were found as nymphs. For this species only 5, mainly old, localities in Serbia have been published: Čemerno Mountain (Pančić, 1883); Golija Mountain (Stevanović, 1953); Kopaonik Mountain (Čejchan, 1961), and the mountains Stolovi and Željin (Adamović, 1970).

ECOLOGY: Pratinicole; graminicole.  
*Roeseliana* Zeuner, 1941

25. *Roeseliana roeselii* (Hagenbach, 1822): 1♂, Sopotnica (meadow) (2), 12.07.2015; 2♂♂, same locality,

**ECOLOGY:** Pratinicole; graminicole.


**ECOLOGY:** Silvicole; terricole–arbusticole.


**ECOLOGY:** Pratinicole; graminicole.


**ECOLOGY:** Silvicole; terricole–arbusticole.


**ECOLOGY:** Silvicole; terricole–arbusticole.

*Eupholidoptera* Maran, 1953


**ECOLOGY:** Silvicole; terricole–arbusticole.


**ECOLOGY:** Pratinicole; terricole–graminicole.

**Remarks:** This species was previously recorded on 3 mountains in southern Serbia (Ebner, 1924; Us, 1938; Ramme, 1951; Matvejev, 1965). Jadovnik Mountain represents the northernmost locality of its distribution. Kaya et al. (2015) mention that boundaries with the ranges of 2 other Balkan species are not clear and so it is necessary to investigate the distribution of this genus in southwestern Serbia. Song consists of isolated syllables followed by 1–2 isolated impulses (Figures 13A and 13B). Stridulatory file has 91 teeth (Figure 14), fewer than reported in Kaya et al. (2015).

*Pachytrachis* Uvarov, 1940


**ECOLOGY:** Silvicole; terricole–arbusticole.

*Rhacocleis* Fieber, 1853


**ECOLOGY:** Pratinicole; graminicole.

Bradyporinae Burmeister, 1838

*Ephippiger* Berthold, 1827

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**Figure 13.** *Psorodonotus macedonicus*, oscillograms of male calling song. A) 3 syllables; B) syllable with 2 impulses.
ECOLOGY: Pratinicole–silvicole; arbusticole.

35. Troglophilus cavicola (Kollar, 1833): 2♂ (1 nymph), beech forest (43.305, 19.741), 19.07.2016.  
ECOLOGY: Silvicole; terricole; cavernicole.

ECOLOGY: Pratinicole; terricole.  
*Melanogryllus* Chopard, 1961

ECOLOGY: Pratinicole; terricole.

As only one species was found in this locality, it was not added to the Table.


ECOLOGY: Pratinicole; terricole.  

41. Tetrix bipunctata (Linnaeus, 1758) (Figure 15): 2♂♂, 4♀♀, Mali Jadovnik (meadow) (17), 20.07.2016.  
ECOLOGY: Silvicole; terricole.  

ECOLOGY: Pratinicole; terricole.  

43. Podisma pedestris (Linnaeus, 1758) (Figure 16): 2♂♂, 5♀♀, Vodice (roadside) (10), 18.07.2016; 2♀♀, Ogoreljac–Mali Jadovnik (roadside) (15), 12.07.2015; 1♂, 1♀, same locality, 19.07.2016.  

Figure 14. SEM image of the stridulatory file in *Psorodonotus macedonicus*, Sopotnica Waterfalls.  
Figure 15. *Tetrix bipunctata* (female).
ECOLOGY: Pratinicole; terricole–herbicole.

44. Galvagniella Harz, 1973

**Galvagniella albanica** (Mishchenko, 1952) (Figure 17): 1♂, 2♀♀, Sopotnica Waterfalls (4), 17.07.2016; 3♀♀, Sopotnica (forest meadow) (5), 18.07.2016; 1♂, 1♀♀, Čelina (6), 18.07.2016; 1♂, Čelina (forest edge) (7), 18.07.2016; 1♂, 1♀♀, Vodice (9), 18.07.2016.

ECOLOGY: Pratinicole–silvicole; herbicole.

**Pseudopodisma** Mishchenko, 1947

45. **Pseudopodisma fieberi** (Scudder, 1897): 5♂♂, 2♀♀, Gvozd (20), 20.07.2016.

ECOLOGY: Pratinicole–silvicole; herbicole

**Odontopodisma** Dovnar-Zapolskij, 1932


ECOLOGY: Pratinicole; herbicole–arbusticole.

**Catantopinae** Brunner von Wattenwyl, 1893

**Pezotettix** Burmeister, 1840


ECOLOGY: Pratinicole; herbicole–arbusticole.

**Calliptaminae** Tinkham, 1940

**Calliptamus** Serville, 1831


ECOLOGY: Pratinicole; terricole–herbicole.

**Paracaloptetus** Bolivar, 1878


ECOLOGY: Pratinicole–silvicole; terricole–herbicole.

**Oedipodinae** Walker, 1871

**Psophus** Fieber, 1853


ECOLOGY: Pratinicole; terricole.

**Locusta** Linnaeus, 1758


ECOLOGY: Pratinicole.

Remarks: Previous findings of **L. migratoria** in Serbia were reported from the Danube (Pančić, 1883; Graber, 1870; Grebenščikov, 1949; Adamović, 1970a), and one from Prokuplje (Us, 1938). As there were no marshes or larger swampy areas, which are typical habitats for this species, it is possible that this specimen had flown from the Lim River, where suitable habitats for hygrophilous Orthoptera species are present.

**Oedipoda** Latreille, 1829


ECOLOGY: Pratinicole; terricole.

**Aiolopus** Fieber, 1853

ECOLOGY: Pratinicole; terricole–graminicole.

54. Arcyptera fusca (Pallas, 1773): 1♂, Mali Jadovnik (meadow) (17), 30.08.2016.

ECOLOGY: Pratinicole; terricole–herbicole.

55. Euthystira Fieber, 1852


ECOLOGY: Pratinicole–silvicole; terricole–herbicole.


ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Pratinicole; graminicole.

59. Stenobothrus rubicundulus Kruseman & Jeekel, 1967 (Figure 18): 6♀♀, 3♀♀, Vodice (9), 18.07.2016.

ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Silvicole; graminicole–arbusticole.


ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Pratinicole; terricole–graminicole.


ECOLOGY: Pratinicole; graminicole.

Remarks: Members of Chorthippus biguttulus group are easily recognizable by their calling song; this method was applied for their identification on the field. At locality Mali Jadovnik–forest roadside, male calling songs observed in the field were similar to the song of Chorthippus bornhalmi Harz, 1971. As collected males did not produce song in captivity, the number of pegs, which is one of the useful morphological characters for determination of members of the C. biguttulus group (Willemse et al., 2009), was used. Two analyzed males had 105 and 108 stridulatory pegs, which is in the upper border of the range in C. biguttulus and the lower border of the range in C. bornhalmi (Willemse et al., 2009). C. bornhalmi was reported for the first time in Serbia 2 years ago (Skejo and Ivković, 2015) and so it is possible that this species is present in this part of Serbia too; additional analyses of calling songs in the future will show the real status of the species, which is found in the locality Mali Jadovnik–forest roadside.


ECOLOGY: Pratinicole; graminicole.
ECOLOGY: Pratinicole; graminicole.

ECOLOGY: Pratinicole; graminicole.

Altogether, 68 species belonging to 15 subfamilies (6 families) have been recorded. This number represents 38% of the total species number of Serbia. The dominant family is Acrididae MacLeay, 1821 with 26 species, followed by Tettigoniidae with 18 species, Phaneropteridae with 13%, and Gryllidae with 12%. The species are regarded as pratinicole (67%). Graminicole species are in the second position with 22%; next are pratinicole to silvicole with 14% of the species, terricole with 13%, herbicole with 12%, terricole to graminicole with 9%, herbicole to arbusticole 6%, and arbusticole with 4% of the species. Herbicole to arboricole, arboricole, graminicole to arboricole, graminicole to arbusticole, graminicole to herbicole, and cavernicole are present with 1% of the species.

The species *Barbitistes servicauda, Leptophyes discoidalis, Eupholidoptera schmidtii, Tettix bipunctata, and Myrmeleotettix maculatus* are recorded for the first time in this part of Serbia, while *M. brachyptera* and *L. migratoria* represent the first records after 40 years in this country. When compared with the literature data of 2 neighboring mountains—Golija (Grebenščikov, 1950; Stevanović, 1953), with 27 species, and Zlatibor (Brunner von Wattenwyl, 1882; Pančić, 1883; Adamović, 1975), where 19 species were recorded—the presence of 68 species shows that Jadovnik Mountain has rich diversity of Orthoptera. Results published in Ingrisch and Pavićević (2012), where they recorded 87 species in Durmitor, suggest that future studies may show an even higher diversity on Jadovnik Mountain.

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