BIOACOUSTICS IN BUSH-CRICKETS, CRICKETS AND GRASSHOPPERS (INSECTA: ORTHOPTERA) FROM CIUCAŞ MOUNTAINS (EASTERN CARPATHIANS, ROMANIA)

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Abstract. *An investigation on bush-crickets, crickets and grasshoppers (Orthoptera) ethology in Ciucaş Mountains took place during 2008-2011 and the results are presented in this paper. It is an already known fact that the majority of Orthoptera can be easily identified by listening to their particular calling songs, so the oscillographic and spectrographic sound analysis for 36 species is detailed: 19 bush-crickets, 3 crickets and 14 grasshoppers.*
Keywords*: Orthoptera, bioacoustics, Ciucaş Mountains*

Rezumat. *În lucrare sunt prezentate rezultatele studiului autorilor asupra etologiei cosaşilor, greierilor şi lăcustelor din Munţii Ciucaş, în perioada 2008-2011. Este bine ştiut faptul că ortopterele pot fi identificate uşor ascultându-le stridulaţia specifică, aşadar detaliem analiza oscilografică şi spectrografică pentru 36 de specii: 19 cosaşi, 3 greieri şi 14 lăcuste.*
Cuvinte cheie*: Orthoptera, bioacoustică, Munţii Ciucaş*

Introduction

Ciucaş Mountains, the southern part of the Eastern Carpathians, cover a relatively small area - but are very rich in natural beauty. To the south of the highest Peak, Ciucaş (1954 m) there are several notable cliffs: Tigăile Mari, Tigăile Mici, Babele la Sfat, Turnul lui Goliat, Mâna Dracului. A little farther to the South-east raises the sharp ridge Zăgan - Gropşoarele (alpinet.org, 2011). Despite the relatively low altitude, the Ciucaş Mountains impose themselves among the surrounding mountains, lower in altitude and completely different in aspect: Grohotiş Mountains towards West and Siriu Mountains towards East, both bald and grassed (Hera, 2007). It consists of Cretacic conglomerates made from crystalline, sedimentary (limestone) or eruptive-basaltic elements, linked by a limestone-gresous cement.

Ciucaş Mountain is listed as a special area of conservation in the Romanian „Nature 2000" network. The subalpine meadows are successively surrounded by relict spruce and larix forests, both pure and mixed, followed by mixed coniferous and deciduous forests, and pure beech forests. Ciucaş Mountains includes an important biological and ecological diversity that has an incomplete inventory.

Until the present study, no other faunistic data was available on the Orthoptera inhabiting these mountains. As an already known fact, most of the singing Orthoptera can be easily identified by simply listening to their particular calling songs. In many cases, an oscillographic and spectrographic sound analysis is required in order to separate sister-species and it proves to be very reliable in case of the morphological cryptic ones.

Material and methods

Since 2008, we performed systematic expeditions in Ciucaş Mountains, during which a new species of *Isophya* was discovered and described from this area (Iorgu, Iorgu, 2010).

Audio recordings were taken with the digital audio recorders SONY ICD SX56 and EDIROL R-09HR, the latter having a frequency response of 20-40.000 Hz. Due to those recording conditions and as most of the species have frequencies ranging above 40 kHz, we could not determine the maximum peak in all cases. Sound analysis was performed with the software Audacity 1.3 and Batsound 4. All recordings of Caelifera were taken from males with only one posterior leg, so that the oscillogram analysis could be better understood. Also the air temperature was registered during each recording.

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For the oscillogram analysis we used the terminology from Ragge, Reynolds (1998) and Heller *et al.* (2004): *calling song* - song produced by an isolated male; *syllable* - the sound produced by one to-and-fro movement of the stridulatory apparatus; *echeme* - a first-order assemblage of syllables; *impulse* - the highly damped sound impulse arising as the impact of one tooth of the stridulatory file; *after-click* - click produced with considerable delay after the main impulse group.

Results

In this study, 36 Orthoptera species were audio recorded: 19 bush-crickets, 3 crickets and 14 grasshoppers. A detailed oscillographic and spectrographic analysis was performed for each of them. Only frequencies in the interval 0.02-40 kHz were considered.

Suborder Ensifera
Family Phaneropteridae

***Phaneroptera falcata* (Poda, 1761)**
Audio recorded material: 2♂♂, Cheia, 05.09.2011 (19°C).
Bioacoustics. The species sings in the evening and at night during the summer; in autumn it can be heard also during daytime. Males sing isolated syllables or echemes formed of 11-14 syllables. Syllables usually last for about 79-96 ms and echemes for about 1200-1600 ms. Spectrographic analysis of the sound: maximum frequencies located between 15-33 kHz, with highest peak at 21 kHz (Figs. 1a, 2a, 7, 8, 9a).

***Leptophyes albovittata* (Kollar, 1833)**
Audio recorded material: 1♂, Cheia, 29.07.2011 (26°C).
Bioacoustics. This bush-cricket sings mainly in the afternoon and at night. 9 up to 18 impulses form a syllable that lasts for 23-45 ms, with the maximum frequencies in the range of 20 kHz and up to more than 40 kHz (Figs. 1b, 2b, 7, 8, 9b).

***Isophya camptoxypha* (Fieber, 1854)**
Audio recorded material: 3♂♂ 2♀♀, Muntele Roşu Peak, 27.06.2008 (24ºC); 5♂♂ 2♀♀, Muntele Roşu cabin, 18.07.2009 (27ºC); 7♂♂ 1♀, Muntele Roşu Peak, 21.08.2009 (25ºC); 5♂♂, Muntele Roşu cabin, 17.07.2010 (24ºC); 6♂♂ 4♀♀, Muntele Roşu Peak, 13.08.2010 (26ºC).
Bioacoustics. Males sing mainly in the afternoon and at night with a long series of short syllables. We also recorded short bursts of 9-27 syllables that lasted for 12-25 s. Each syllable is formed of 8-16 impulses and lasts for 16-42 ms. Sometimes after-clicks can be observed, following the syllable at 17-51 ms. Maximum sound frequency ranges located at 25 kHz (Figs. 1c, 2c, 7, 8, 9c). between 17 and more than 40 kHz. Highest peak

***Isophya ciucasi* Iorgu & Iorgu, 2010**
Audio recorded material: 2♂♂, Ciucaş cabin, 27.06.2008 (24ºC); 3♂♂ 3♀♀, Ciucaş cabin, 17.07.2009 (27ºC); 19♂♂ 6♀♀, Tigăile Mari Peak, 17.07.2010 (24ºC); 7♂♂, Ciucaş cabin, 14.08.2010 (26ºC), 3♂♂, Tigăile Mari Peak, 29.07.2011.
Bioacoustics. We observed the species singing in the afternoon and at dusk. The song consists of short or long series of syllables, sometimes lasting more than 3 minutes. The short syllable (7-26 impulses, 9-24 ms) is always followed by a number of 13-29 after-clicks. The interval between successive syllables is about 320-600 ms. Acoustic frequency: maximum between 15 and more than 40 kHz, highest peak at about 20 kHz (Figs. 1d, 2d, 7, 8, 9d).

***Poecilimon affinis* (Frivaldsky, 1867)**
Audio recorded material: 2♂♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 4♂♂, Muntele Roşu cabin, 18.07.2009 (25ºC); 3♂♂, Muntele Roşu cabin, 21.08.2009 (25ºC); 2♂♂, Berii springs, 18.07.2010 (24ºC); 4♂♂ 1♀, Muntele Roşu Peak, 13.08.2010 (26ºC).
Bioacoustics. The species sings in the afternoon and evening, sometimes in the morning. A single, loud syllable, lasting for 125-294 ms, is repeated at regular time intervals - about 1.9-3 s. The calling song frequency ranges from 5-35 kHz, with maximum peak at about 16 kHz (Figs. 1e, 2e, 7, 8, 9e).

***Poecilimon schmidtii* (Fieber, 1853)**
Audio recorded material: 1♂, Cheia, 14.08.2010 (26ºC).
Bioacoustics. The species is also crepuscular, singing a variable series of syllables, from 2 up to more than 30. Each syllable is very short - consisting of 2-3 impulses. In a series, the time interval between successive syllables is about 1.3-2 s. The stridulation maximum frequency ranges between 10 and more than 40 kHz (Figs. 1f, 2f, 7, 8, 9f).

***Polysarcus denticauda* (Charpentier, 1825)**
Audio recorded material: 3♂♂, Muntele Roşu Peak, 19.07.2009 (27ºC); 5♂♂, Ciucaş cabin, 18.07.2010 (24ºC).
Bioacoustics. The species stridulates during daytime, especially in warm sunny days. The long series of syllables (repeated at a rate of about 14-17/s) is interrupted by a short series of 8-11 clicks

after variable time periods. The syllable rate tends to increase before the series of clicks, reaching about 35-50/s. There are 3 different periods in the syllable series, each characterized by diverse syllable types. Syllables normally last for about 37-44 ms; before the click series syllables last 19-25 ms. Sound frequency: maximum between 8-35 kHz, with a peak at 14 kHz (Figs. 1g, 2g, 7, 8, 9g).

Family Conocephalidae

***Conocephalus fuscus* (Fabricius, 1793)**

Audio recorded material: 2♂♂, 17.07.2009 (27ºC).

Bioacoustics. The species stridulates a long series of echemes during daytime and rarely at dusk. Each echeme is formed of 3 syllables and each syllable consists of 2 different hemisyllables; the opening hemisyllables are much shorter than the closing ones. Maximum audio frequency: 10 up to more than 40 kHz, highest peak at about 30 kHz (Figs. 1h, 2h, 7, 8, 9h).

Family Tettigoniidae

***Tettigonia viridissima* (Linnaeus, 1758)**

Audio recorded material: 2♂♂, Muntele Roşu cabin, 18.07.2010 (24ºC).

Bioacoustics. The Great Green Bush-cricket sings at dusk and during the first few hours of night; in late summer and autumn it also stridulates in daytime. The song is formed of a long series of disyllabic echemes, repeated at a rate of about 14-16/s and lasting for a few minutes. Carrier wave frequency ranges between 5 and up to more than 40 kHz, maximum peak recorded at about 12 kHz (Figs. 1i, 2i, 7, 8, 9i).

***Decticus verrucivorus* (Linnaeus, 1758)**

Audio recorded material: 1♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 3♂♂, Cheia, 17.07.2009 (27ºC); 2♂♂, Muntele Roşu cabin, 18.07.2009 (27ºC); 2♂♂, Cheia, 14.08.2010 (26ºC).

Bioacoustics. The species sings a long series of tetrasyllabic echemes in warm sunny days. In cloudy days it only sings isolated echemes. Each echeme lasts for about 38-50 ms and time interval between successive echemes is 47-65 ms. Frequency of the sound ranges between 6 up to more than 40 kHz; maximum frequency recorded at 12 kHz (Figs. 1j, 2j, 7, 8, 9j).

***Metrioptera roeselii* (Hagenbach, 1822)**

Audio recorded material: 1♂, Cheia, 17.07.2009 (27ºC); 4♂♂, Muntele Roşu cabin, 18.07.2010 (24ºC).

Bioacoustics. The species stridulate mainly during sunny days. The song is a long series of syllables, repeated at a rate of about 81-94/s. Sound frequency: 7 up to more than 40 kHz, with peak at 17 kHz (Figs. 1k, 2k, 7, 8, 9k).

***Metrioptera bicolor* (Philippi, 1830)**

Audio recorded material: 1♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 2♂♂, Cheia, 17.07.2009 (27ºC); 5♂♂, Muntele Roşu Peak, 19.07.2009 (27ºC); 1♂, Muntele Roşu cabin, 20.08.2009 (25ºC); 6♂♂, Ciucaş cabin, 18.07.2010 (24ºC).

Bioacoustics. The song can be heard during daytime and consists of a variable series of trisyllabic echemes, lasting for about 20-27 ms. Successive echemes are repeated after 15-20 ms. Acoustic frequency: 8 up to more than 40 kHz, maximum at about 20 kHz (Figs. 1l, 2l, 7, 8, 9l).

***Metrioptera brachyptera* (Linnaeus, 1761)**

Audio recorded material: 1♂, Cheia, 17.07.2009 (27ºC); 3♂♂, Muntele Roşu Peak, 19.07.2009 (27ºC); 4♂♂, Tigăile Mari Peak, 17.07.2010 (24ºC).

Bioacoustics. The calling song is a long series of tetrasyllabic echemes. Each echeme lasts for about 82-98 ms and the interval between successive echemes is 70-90 ms. Maximum stridulation frequency ranges between 10-40 kHz, highest peak at about 22 kHz (Figs. 3a, 4a, 7, 8, 9m).

***Platycleis albopunctata grisea* (Fabricius, 1781)**

Audio recorded material: 1♂, Cheia, 17.07.2010 (28ºC).

Bioacoustics. The calling song consists of a variable series of tetra- or pentasyllabic echemes; an echeme lasts for 250-300 ms and the period between two successive echemes is 420-480 ms. Audio frequency: 10-39 kHz, with maximum at about 18 kHz (Figs. 3b, 4b, 7, 8, 9n).

***Pholidoptera griseoaptera* (De Geer, 1773)**

Audio recorded material: 2♂♂, Cheia, 17.07.2009 (28ºC); 1♂, Berii springs, 18.07.2010 (24ºC); 1♂, Cheia, 29.07.2011 (26ºC).

Bioacoustics. Males sing in the afternoon, at dusk and during the night. The song consists of very short echemes, repeated at irregular time intervals. Each echeme is composed of 3 syllables, lasting for about 80-110 ms. Calling song frequency ranges between 7 up to more than 40 kHz, with a peak at about 25 kHz (Figs. 3c, 4c, 7, 8, 9o).

***Pholidoptera fallax* (Fischer, 1853)**
Audio recorded material: 1♂, Muntele Roşu cabin, 17.07.2010 (24ºC).
Bioacoustics. The song is rarely produced during daytime, but mainly at dusk. The echeme structure is similar with *Pholidoptera griseoaptera*, each echeme being composed of 3 syllables. In a syllable, the sound amplitude constantly raises from beginning to the end. Echemes are short, of about 50-90ms. The frequency of sound ranges between 8 and more than 40 kHz, with the highest peak at 12 kHz (Figs. 3d, 4d, 7, 8, 9p).

***Pholidoptera littoralis similis* (Brunner von Wattenwyl, 1861)**
Audio recorded material: 3♂♂, Babarunca, 21.08.2009 (25ºC).
Bioacoustics. The species sings during daytime, at dusk and at night. The echeme is long, lasting for 1.1-1.9 s. It consists of 21-33 syllables, each syllable lasting for about 19-23 ms. Echemes are repeated at irregular time periods. Acoustic frequency is between 5 and more than 40 kHz; highest peak at about 8 kHz (Figs. 3e, 4e, 7, 8, 9q).

***Pholidoptera transsylvanica* (Fischer, 1853)**
Audio recorded material: 5♂♂, Muntele Roşu cabin, 29.07.2011 (25°C).
Bioacoustics. This endemic Carpathian bush-cricket sings mainly in the after-noon in mid-summer, but in late summer and autumn, when temperatures drop, it sings during daytime. The song consists of an echeme sequence, echemes being formed of 3 (rarely 4) syllables. The spectrum is very similar with the one in *Pholidoptera fallax* and *P. littoralis*, the frequencies ranging from 4 and up to more than 40 kHz, highest peak at about 7 kHz (Figs. 3f, 4f, 7, 8, 9r).

Family Bradyporidae
***Ephippiger ephippiger* (Fiebig, 1784)**
Audio recorded material: 1♂, Cheia, 17.07.2010 (25ºC).
Bioacoustics. The Saddle-backed Bush-cricket sings during time and at dusk a series of short syllables. Typically each syllable (100-190 ms) consists of 2 different hemisyllables, a short opening hemisyllable and a long closing hemisyllable. Sometimes 2 or 3 syllables are singed together in an echeme. Maximum sound frequency: from 8 up to 36 kHz (Figs. 3g, 4g, 7, 8, 10a).

Family Gryllidae
***Gryllus campestris* Linnaeus, 1758**
Audio recorded material: 1♂, Cheia, 17.07.2010 (25ºC).
Bioacoustics. Males typically sing in the evening and at night, but day songs have also been recorded - especially in the summer. Each short echeme consists of 4 syllables, each syllable lasting for about 19-27 ms. In a syllable, the sound reaches the maximum amplitude at midlength. Carrier wave frequency: 3-20 kHz, maximum at about 5 kHz (Figs. 3h, 4h, 7, 8, 10b).

***Pteronemobius heydenii* (Fischer, 1853)**
Audio recorded material: 3♂♂, Muntele Roşu cabin, 17.07.2010 (24ºC).
Bioacoustics. This cricket can be heard singing during daytime and in the dusk, usually in hygrophilous grasslands. The echeme lasts for about 1.9-3.4 s and consists of 80-110 syllables. From beginning to the end, the sound amplitude grows higher in each echeme. Audio frequency: 7 up to 26 kHz, with the highest peak at about 8.5 kHz (Figs. 3i, 4i, 7, 8, 10c).

***Oecanthus pellucens* (Scopoli, 1763)**
Audio recorded material: 2♂♂, Cheia, 05.09.2011 (19°C).
Bioacoustics. The Tree-cricket sings during the night in summer and sometimes during daytime in autumn. An echeme consists of 16-24 syllables and lasts for about 200-360 ms. The sound has a frequency of 2-18 kHz, highest peak at 3.5 kHz (Figs. 3j, 4j, 7, 8, 10d).

Suborder Caelifera
Family Acrididae
***Euthystira brachyptera* (Ocskay, 1826)**
Audio recorded material: 3♂♂, Muntele Roşu Peak, 19.07.2009 (27ºC); 6♂♂, Muntele Roşu cabin, 17.07.2010 (24ºC).
Bioacoustics. Males sing in summer sunny days. The short echemes (360-430 ms) are composed of 8-11 syllables. Each syllable lasts for 30-60 ms. Carrier wave frequency: 5 up to more than 40 kHz, maximum peak at about 10 kHz (Figs. 3k, 4k, 7, 8, 10e).

***Chrysochraon dispar* (Germar, 1831)**
Audio recorded material: 2♂♂, Babarunca, 21.08.2009 (25ºC).
Bioacoustics. The species sings during sunny days a series of echemes, each one lasting for 1.1-1.8 s. Echemes consist of 9-15 syllables (a syllable lasts for 110-137 ms). Maximum stridulation frequency

ranges between 6 and more than 40 kHz; peak at 12 kHz (Figs. 3l, 4l, 7, 8, 10f).

***Omocestus rufipes* (Zetterstedt, 1821)**
Audio recorded material: 1♂, Cheia, 05.09.2011 (19°C).
Bioacoustics. The Woodland Grasshopper sings especially in the warm sunny days, since June up to October. The song consists of long echemes, lasting for 4-10 s, composed of 69-170 syllables. Audio frequency: 3 up to more than 40 kHz, with maximum at about 16 kHz (Figs. 5a, 6a, 7, 8, 10g).

***Omocestus viridulus* (Linnaeus, 1758)**
Audio recorded material: 3♂♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 6♂♂, Muntele Roşu Peak, 18.07.2009 (27ºC); 1♂, Muntele Roşu cabin, 21.08.2009 (23ºC); 2♂♂, Muntele Roşu cabin, 17.07.2010 (24ºC); 3♂♂, Muntele Roşu Peak, 13.08.2010 (26ºC).
Bioacoustics. The Common Green Grasshopper sings mainly in sunny days and can be rarely heard in overcast days. The echeme is long and lasts up to 37 s, being formed of 250-520 syllables. Audio frequency: 4 up to more than 40 kHz, with maximum at about 20 kHz (Figs. 5b, 6b, 7, 8, 10h).

***Omocestus haemorrhoidalis* (Charpentier, 1825)**
Audio recorded material: 1♂, Muntele Roşu cabin, 17.07.2009 (27ºC).
Bioacoustics. The song consists of short echemes, lasting for 3.6-5.4 s, each having 49-107 syllables. Sound amplitude rises from beginning to end in each echeme and also in each syllable. Stridulation frequency ranges between 7 up to more than 40 kHz (Figs. 5c, 6c, 7, 8, 10i).

***Stenobothrus lineatus* (Panzer, 1796)**
Audio recorded material: 2♂♂, Muntele Roşu cabin, 29.07.2011 (25°C). It was the only grasshopper recorded while stridulating with both hind legs.
Bioacoustics. The Stripe-winged grasshopper has a particular way to sing, moving slowly and alternatively the hind legs. The echeme lasts for 24-37 s, composed of 19-25 syllables. Audio frequency: 6 and more than 40 kHz, with maximum at about 13 kHz (Figs. 5d, 6d, 7, 8, 10j).

***Stenobothrus stigmaticus* (Rambur, 1839)**
Audio recorded material: 1♂♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 2♂♂, Muntele Roşu cabin, 17.07.2009 (27ºC).
Bioacoustics. Males sing a low intensity echeme, lasting for about 2.4-4 s and composed of 27-50 syllables (each lasting for about 64-82 ms). Audio frequency: 5 up to more than 40 kHz (Figs. 5e, 6e, 7, 8, 10k).

***Gomphocerippus rufus* (Linnaeus, 1758)**
Audio recorded material: 2♂♂, Cheia, 17.07.2009 (28ºC); 2♂♂, Babarunca, 21.08.2009 (25ºC).
Bioacoustics. The species sings a short echeme sequence, lasting for about 5-10 s and consisting of 20-50 echemes. Two syllables with higher amplitude that are followed after a short pause by a dense group of 4-6 syllables with lower amplitude form an echeme. Audio frequency: 8 up to more than 40 kHz, with the highest peak at about 17 kHz (Figs. 5f, 6f, 7, 8, 10l).

***Chorthippus apricarius* (Linnaeus, 1758)**
Audio recorded material: 2♂♂, Cheia, 27.06.2005 (24ºC); 1♂, Cheia, 17.07.2009 (28ºC).
Bioacoustics. Male calling song is a long echeme sequence lasting for about 12-40 s. This echeme sequence is formed by 60-180 echemes. Each echeme consists of a group of 3 syllables, the first one being very short (12-16 ms) but with high amplitude and the following ones longer - each 65-100 ms - and lower in amplitude. Stridulation frequency ranges between 3 - more than 40 kHz. Maximum recorded at 8 kHz (Figs. 5g, 6g, 7, 8, 10m).

***Chorthippus biguttulus* (Linnaeus, 1758)**
Audio recorded material: 1♂, Cheia, 27.06.2008 (25ºC); 3♂♂, Cheia, 17.07.2009 (28ºC); 2♂♂, Cheia, 20.08.2009 (25ºC); 4♂♂, Babarunca, 21.08.2009 (25ºC); 1♂, Cheia, 17.07.2010 (25ºC).
Bioacoustics. Males sing during day time. Echeme sequences are repeated in a short series of 3, rarely 4-7. The first echeme sequence is longer, with about 45-70 echemes, the following ones being shorter, 20-35 echemes. A single echeme is very short (110-250 ms), consisting of 3-6 syllables. Acoustic frequency: 5 - more than 40 kHz, maximum at about 12 kHz (Figs. 5h, 6h, 7, 8, 10n).

***Chorthippus brunneus* (Thunberg, 1815)**
Audio recorded material: 1♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 2♂♂, Cheia, 17.07.2009 (27ºC); 1♂, Muntele Roşu cabin, 19.07.2009 (air temperature 27ºC).
Bioacoustics. Usually males sing during sunny days in very short echemes, lasting for about 0.2-0.3 s and consisting of 10-15 syllables. Carrier wave frequency ranges between 3 and more than

40 kHz. Maximum recorded at 12 kHz (Figs. 5i, 6i, 7, 8, 10o).

***Chorthippus albomarginatus* (De Geer, 1773)**
Audio recorded material: 1♂, Cheia, 29.07.2011 (26°C).
Bioacoustics. This grasshopper sings short echemes series, consisting of 3-5 echemes, each lasting for about 450-570 ms. Typically an echeme consists of 18-25 syllables, the ones in the middle having the lowest amplitude. Audio frequency: 6-35 kHz, with maximum at about 20 kHz (Figs. 5j, 6j, 7, 8, 10p).

***Chorthippus dorsatus* (Zetterstedt, 1821)**
Audio recorded material: 1♂, Cheia, 29.07.2011 (26°C).
Bioacoustics. This species sings during daytime an echeme series composed of 9-13 echemes, each one lasting for 1,9-2,6 s. In an echeme, the first 5-8 syllables are produced with the hind legs moving synchronously, while the last 4-6 syllables are "singed" with the hind legs moving asynchronously. Each syllable is composed of 2 distinct hemisyllable, more easily to be noticed in the echeme's first part. Sound frequency: from 4 up to more than 40 kHz, with maximum peak at 12 kHz (Figs. 5k, 6k, 7, 8, 10q).

***Chorthippus parallelus* (Zetterstedt, 1821)**
Audio recorded material: 2♂♂, Muntele Roşu cabin, 27.06.2008 (24ºC); 3♂♂, Muntele Roşu cabin, 19.07.2009 (27ºC); 2♂♂, Babarunca, 21.08.2009 (25ºC).
Bioacoustics. Males sing during daytime and very rare at dusk a short song, echemes composed of 10-15 syllables. Each echeme lasts for about 1-2 s at about 20-28ºC. Audio frequency: 5 and more than 40 kHz, with maximum at about 21 kHz (Figs. 5l, 6l, 7, 8, 10r).

Discussion

Only few papers deal with some Orthoptera species' acoustic analysis in the Romanian Carpathian Mountains (Orci, 2001; Orci *et al.* 2005; Iorgu, Pisică, 2007; Orci *et al.* 2010a; Orci *et al.* 2010b, Iorgu, Iorgu, 2010).

The present paper offers the first comprehensive analysis on the Orthoptera songs from Ciucaş Mountains, providing a mini acoustic guide - a very useful tool in identifying 36 Orthoptera species, many of those being commonly found in the Romanian Carpathians.

With few exceptions, the sound oscillogram and spectrogram analyses of the studied species revealed no major difference in the song structure of the Carpathian individuals from individuals from the rest of Europe. The song characteristics such as song structure and audio frequency of each studied individual were situated in the normal range of the species, comparing with several data from literature.

In *Isophya camptoxypha*, the syllables from some Central European individuals tend to have a higher number of impulses and length (11-25 impulses and 27-46 ms, in Heller et al. 2004), compared with Ciucaş individuals (8-16 impulses and 16-42 ms).

The studied Carpathian populations of *Poecilimon affinis* sing syllables located in the species' normal range for the Balkan populations analyzed in Chobanov, Heller (2010) and Ingrisch, Pavićević (2010).

In *Tettigonia viridissima,* one of the widespread bush-crickets in Europe, the Western populations have a normal syllable repetition of 10-15/s (Ragge, Reynolds, 1998), the same as in the Carpathians; however in some European populations the rate tends to reach 13-35 syllables/s (Heller, 1988).

Shorter echemes were noted in *Decticus verrucivorus* populations from Ciucaş (38-50 ms), comparing with Ragge, Reynolds, 1998 (45-80 ms), but considered in the species' normal range.

In *Platycleis albopunctata grisea* we observed longer echemes (250-300 ms) than in the nominotypical subspecies (100-200 ms) and faster repeating: 420-480 ms between successive echemes in *P. a. grisea* and 100-300 ms in *P. a. albopunctata* (data from Ragge, Reynolds, 1998).

Shorter echemes are produced in the Carpathian populations of *Pholidoptera griseoaptera* (80-110 ms), compared with the Western Europe populations (150-200 ms) (Ragge, Reynolds, 1998).

The oscillographic component of song analysis in *Pholidoptera transsylvanica* was discussed by Orci (2001); the only noticeable difference is that in Ciucaş the recorded individuals sing echemes formed of 3 syllables, but also echemes consisting of 4 syllables. The species' song spectrum is detailed for the first time in the present paper.

The studied Carpathian individuals of *Euthystira brachyptera* produce longer echemes (8-11 syllables, echemes lasting for 360-430 ms) compared with other Western European populations (4-7 syllables, echemes lasting for 140-300 ms) (Ragge, Reynolds, 1998).

Longer echemes, but with the relatively the same number of syllables, were noticed in the Ciucaş populations of *Stenobothrus lineatus*: 24-37 s against 10-25 s in Western European populations (Ragge, Reynolds, 1998). Also *Chorthippus dorsatus* populations from the Eastern Carpathians

produce longer echemes (1,9-2,6 s s) compared with the Western European populations (0.8-1.5 s) (Ragge, Reynolds, 1998).

All the recorded species, including from closely related groups, can be readily separated by temporal and frequency parameters of the calling songs through oscillogram and sonogram analyses.

Acknowledgements

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Fig. 2. Detailed calling song oscillograms of the Orthoptera males analyzed in Fig. 1: a. *Phaneroptera falcata*; b. *Leptophyes albovittata*; c. *Isophya camptoxypha*; d. *Isophya ciucasi*; e. *Poecilimon affinis*; f. *Pecilimon schmidtii*; g. *Polysarcus denticauda*; h. *Conocephalus fuscus*; i. *Tettigonia viridissima*; j. *Decticus verrucivorus*; k. *Metrioptera roeselii*; l. *Metrioptera bicolor*.

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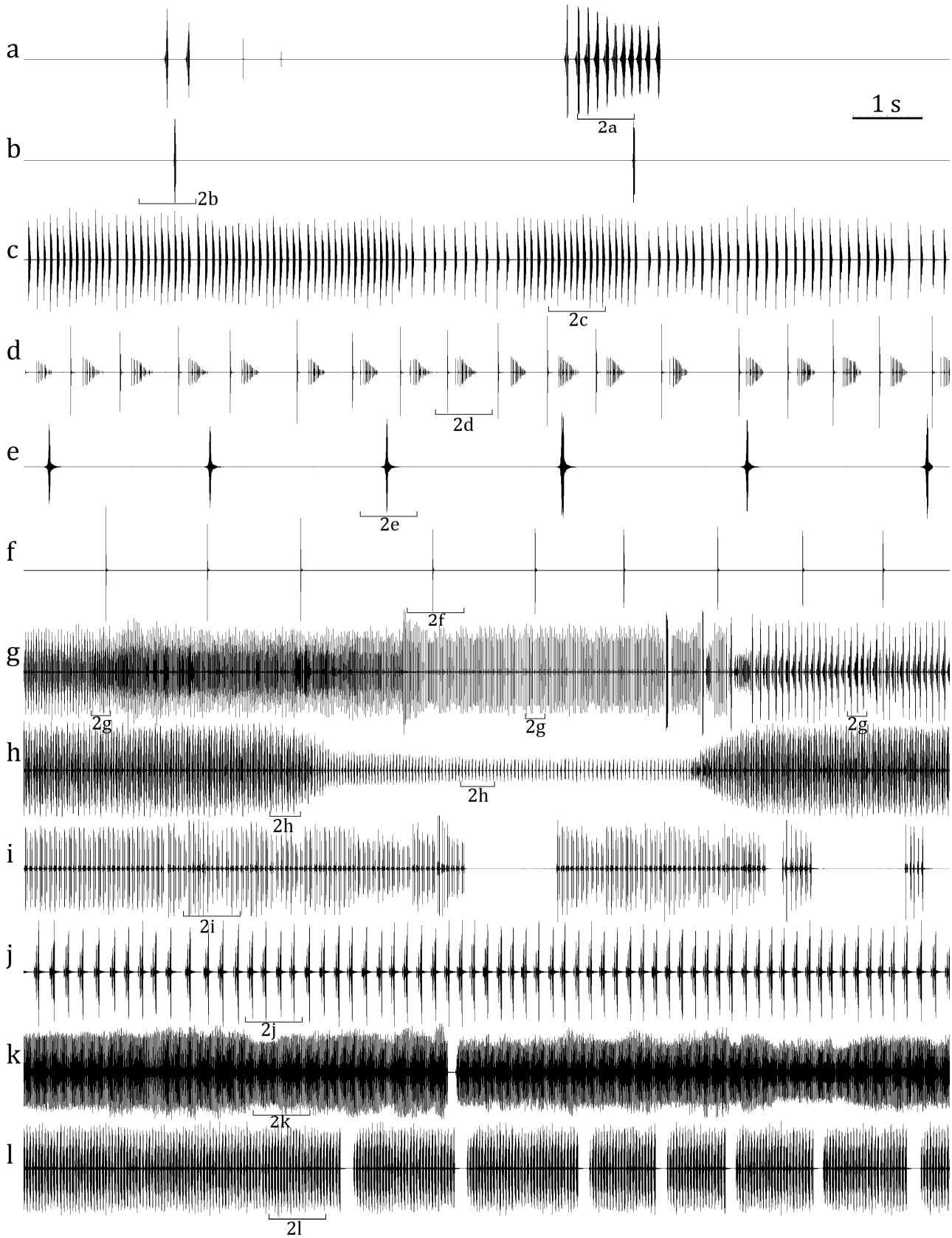


Fig. 1. Oscillographic analysis of the calling song in Orthoptera males recorded in Ciucaş Mountains (I)

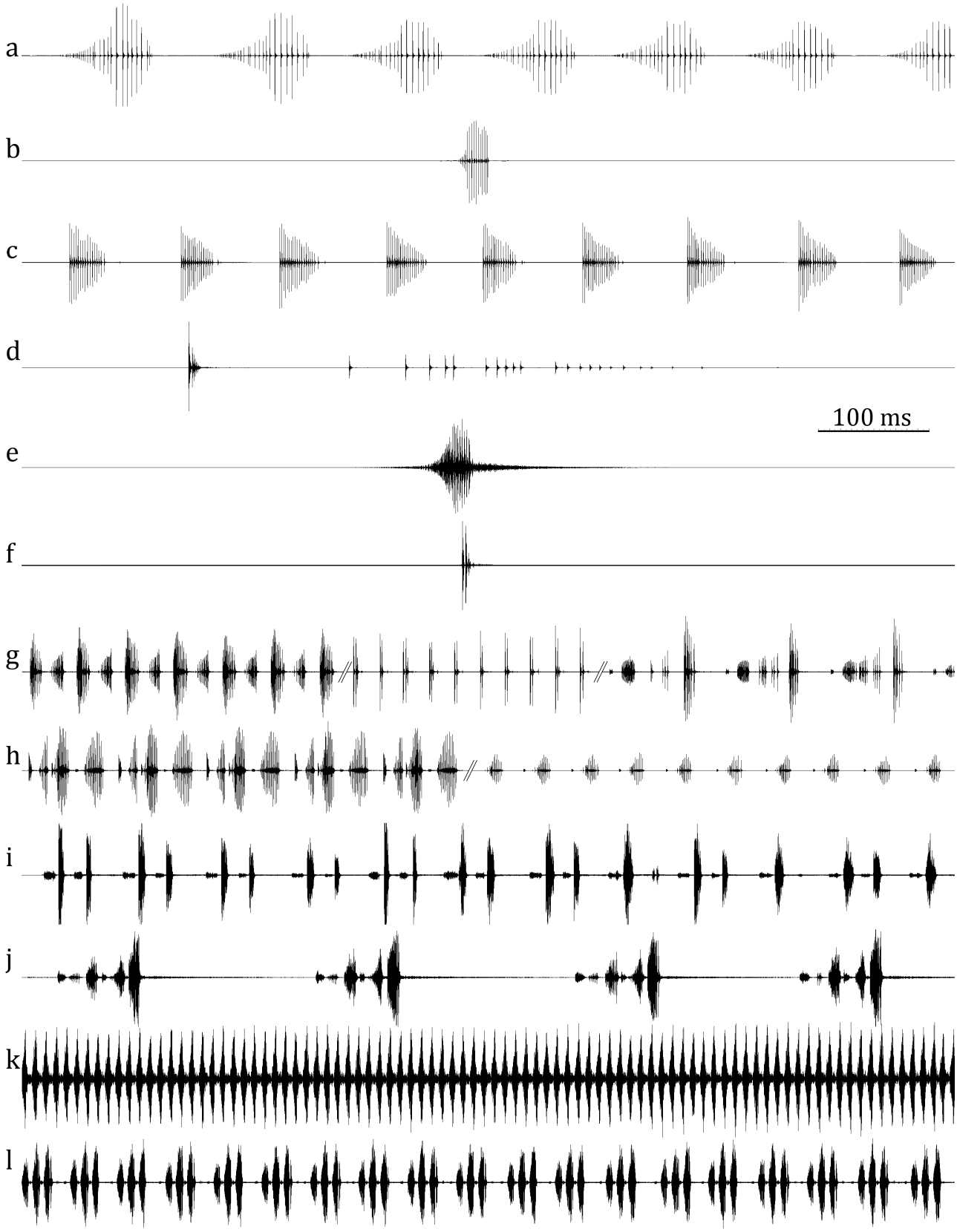


Fig. 2. Detailed calling song oscillograms of the Orthoptera males analyzed in Fig. 1

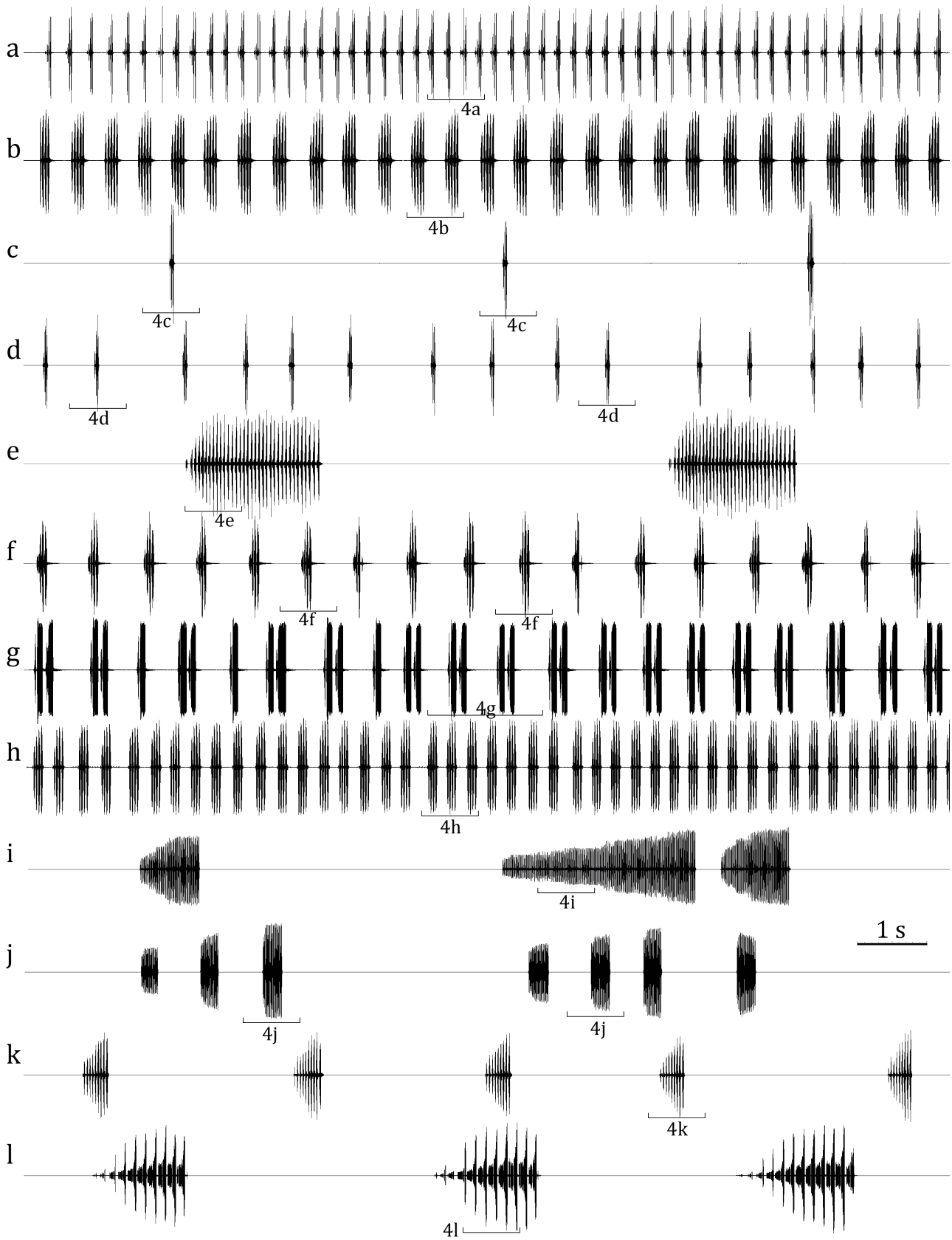


Fig. 3. Oscillographic analysis of the calling song in Orthoptera males recorded in Ciucaş Mountains (II)

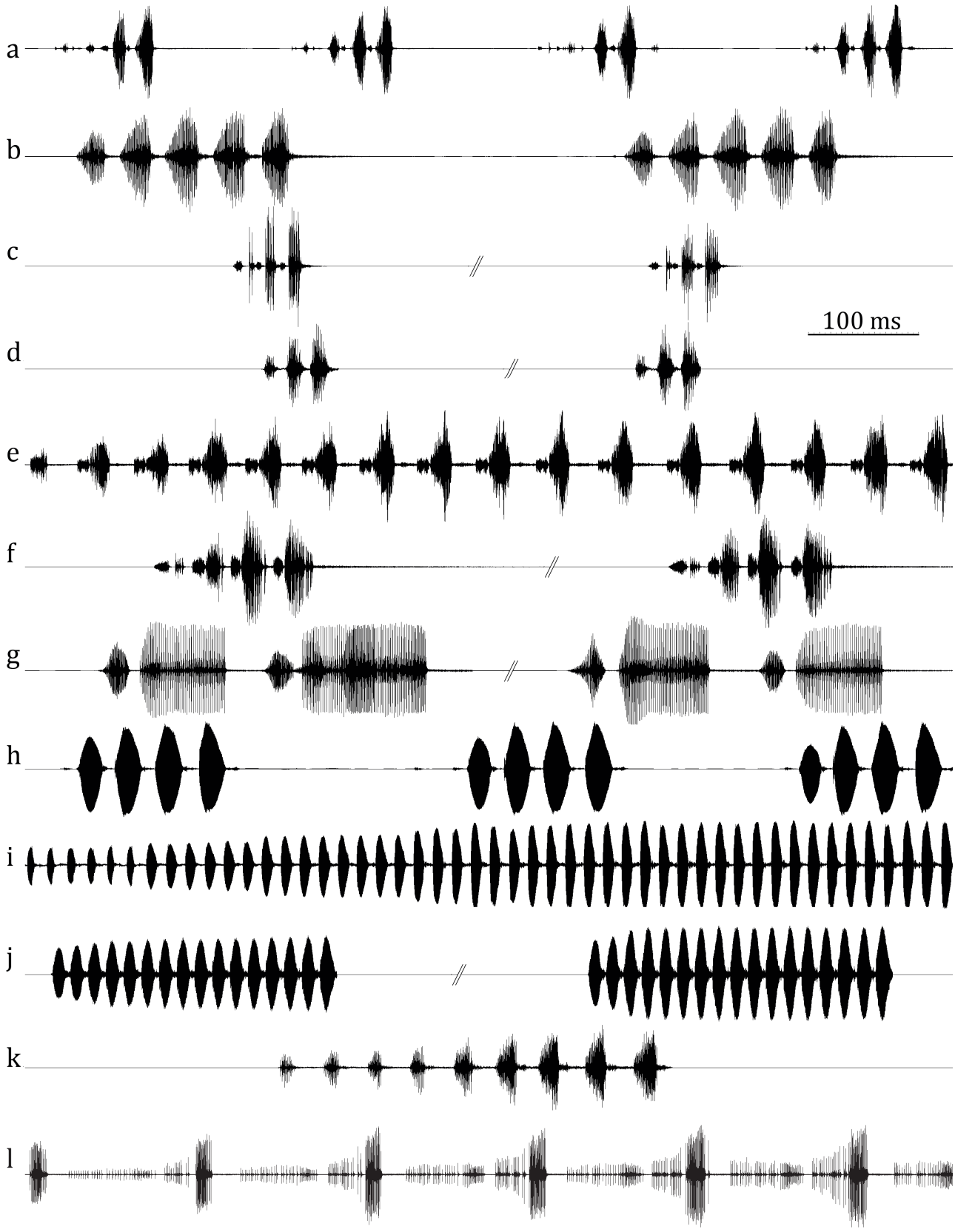
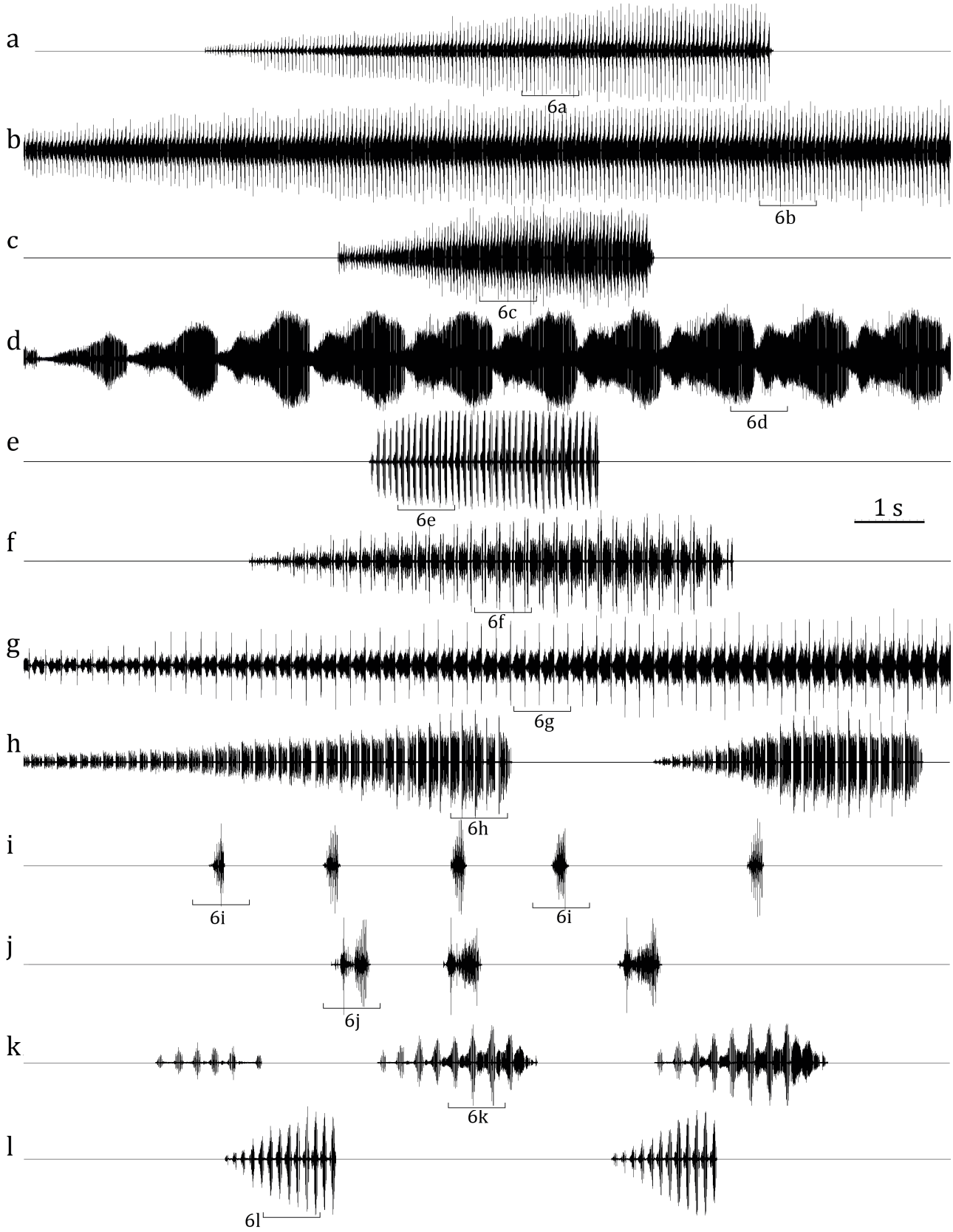


Fig. 4. Detailed calling song oscillograms of the Orthoptera males analyzed in Fig. 3



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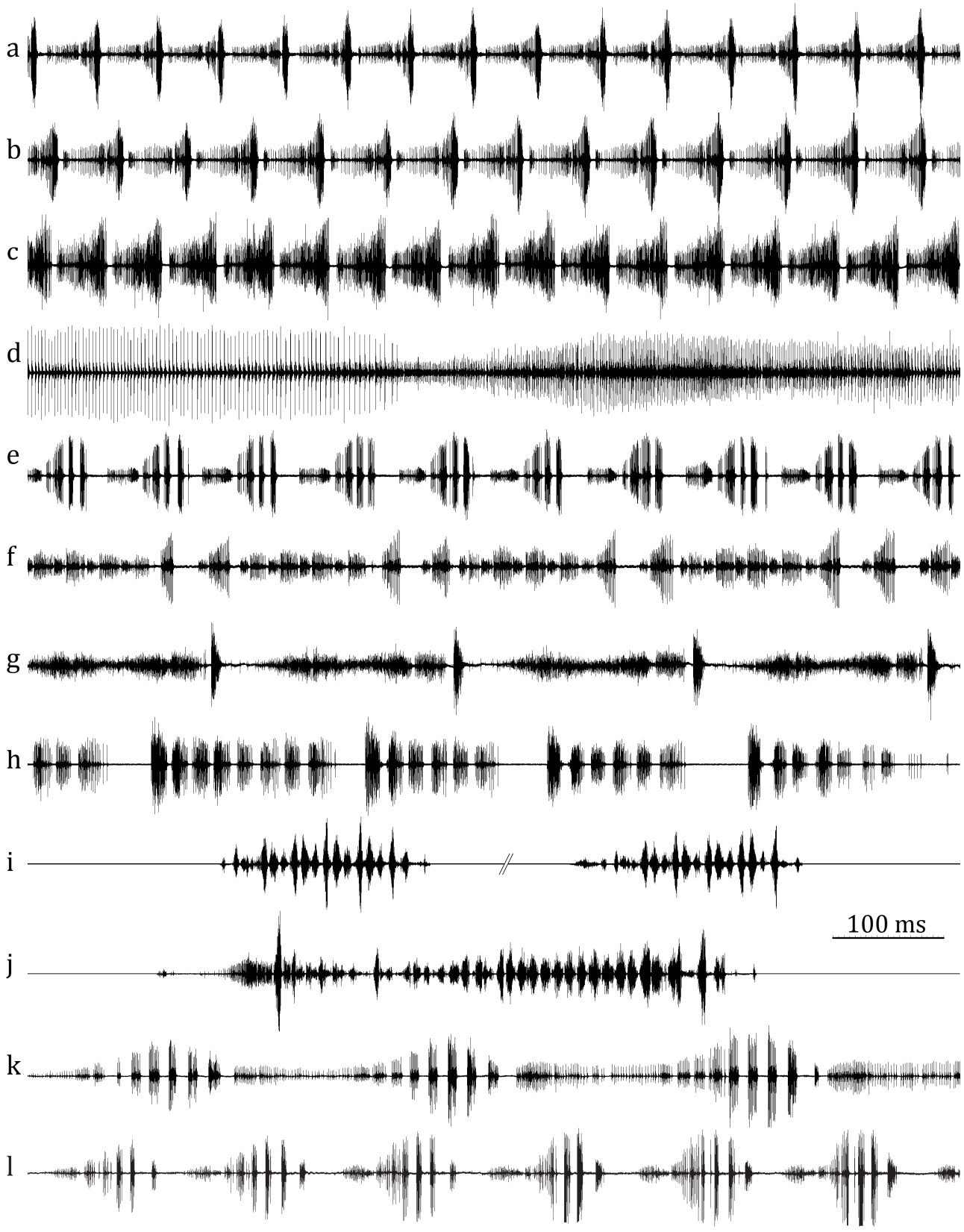


Fig. 6. Detailed calling song oscillograms of the Orthoptera males analyzed in Fig. 5

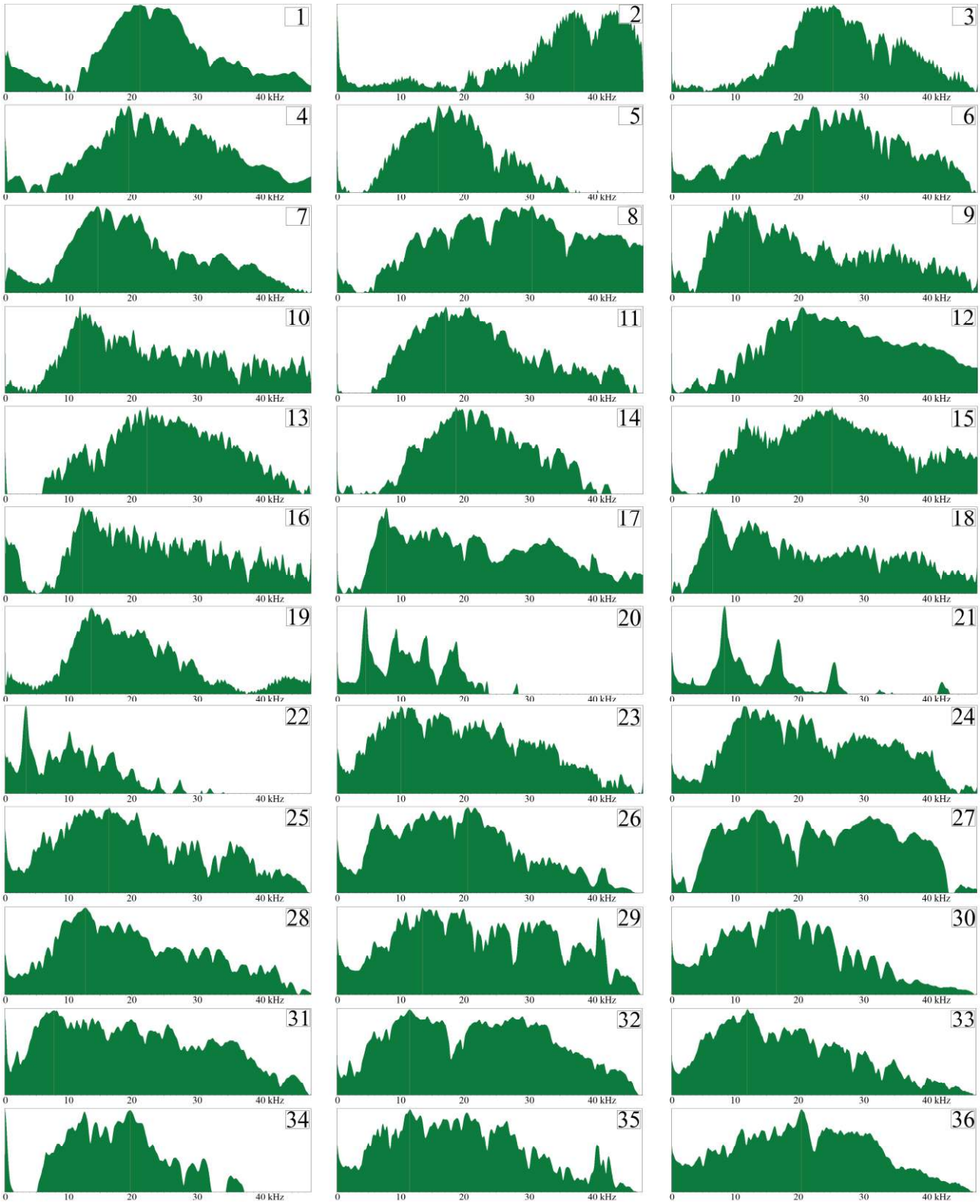


Fig. 7. Sound spectrum in Orthoptera males recorded in Ciucaş Mountains

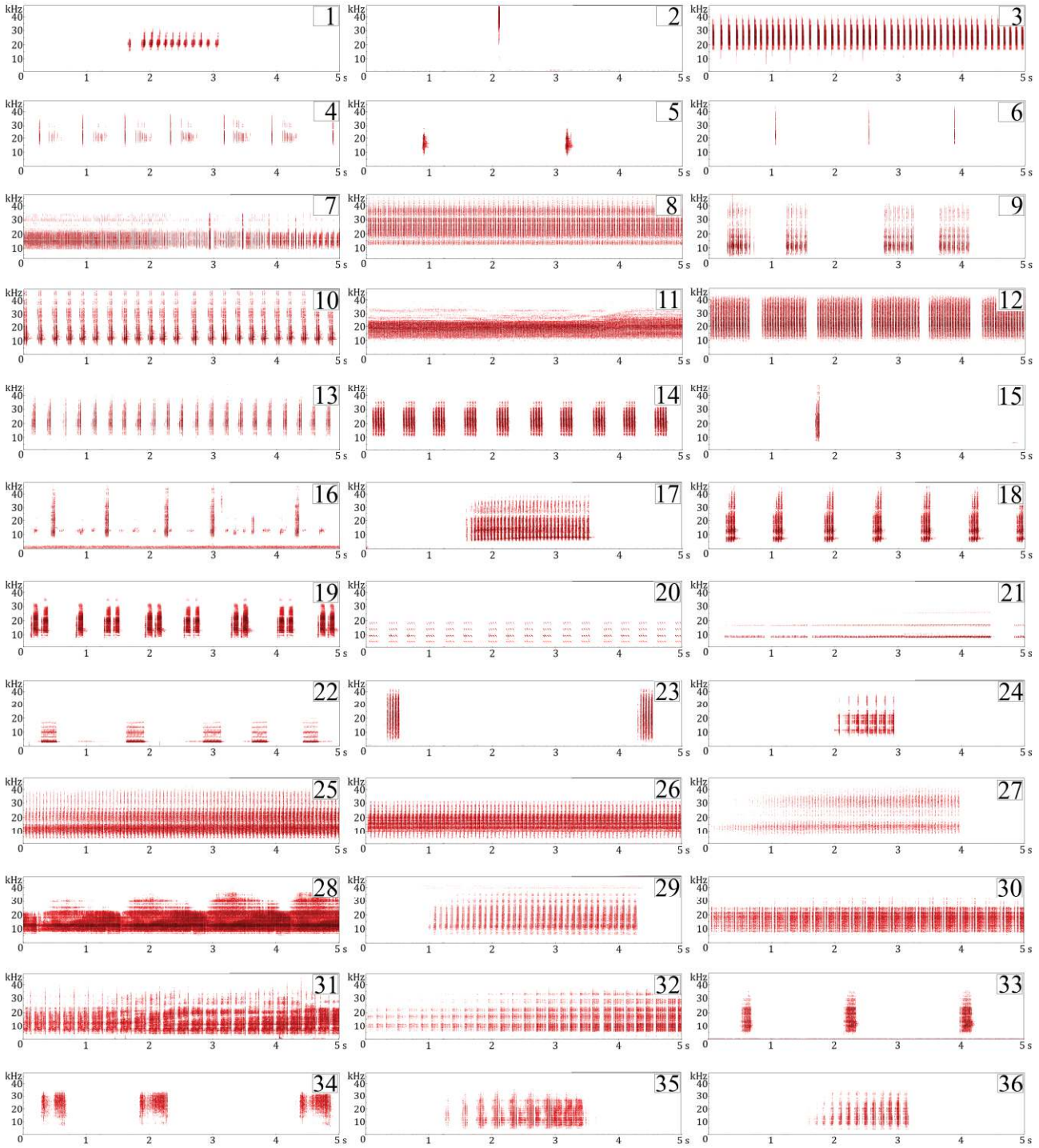


Fig. 8. Sound spectrogram in Orthoptera males recorded in Ciucaş Mountains:

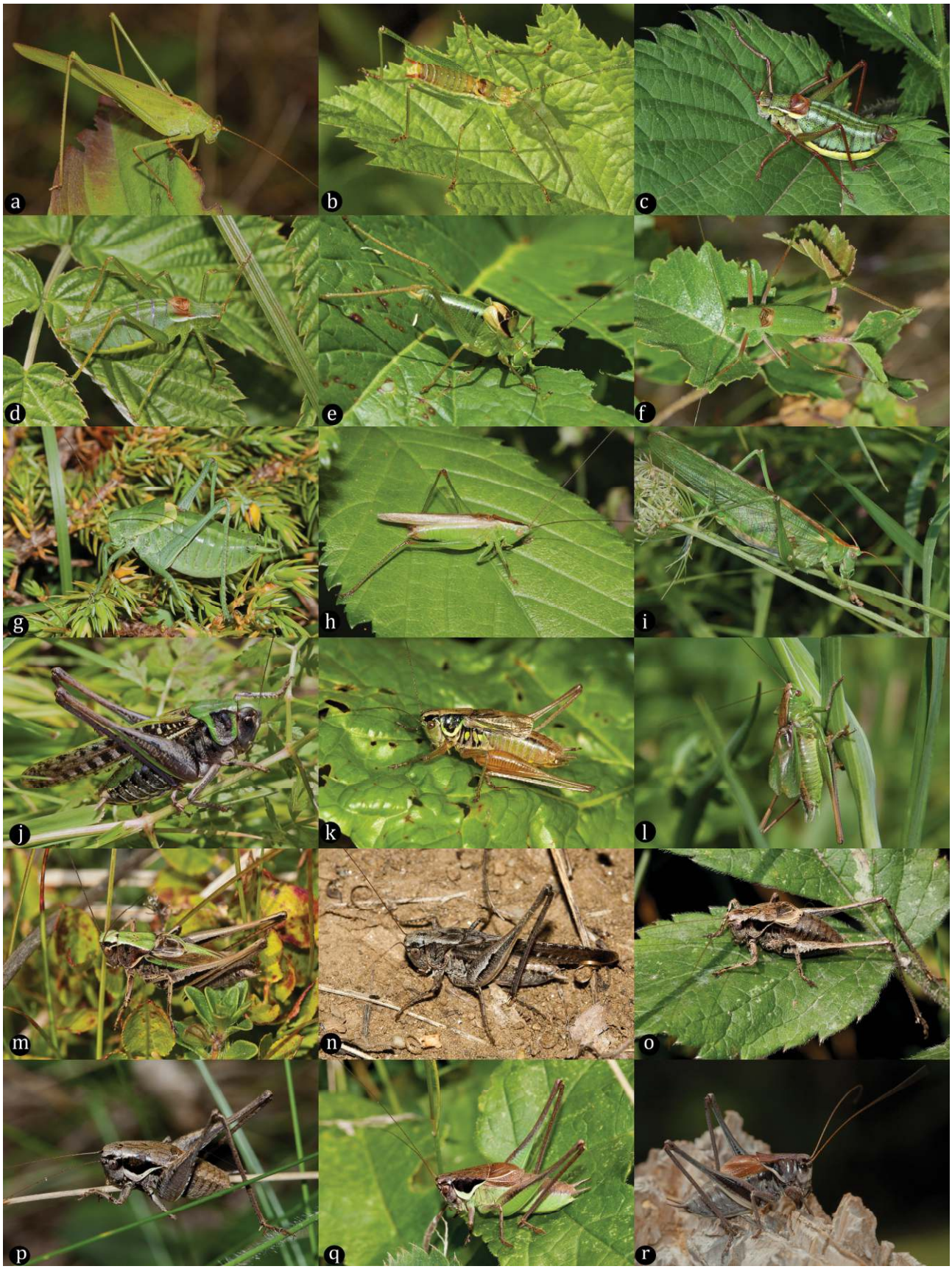
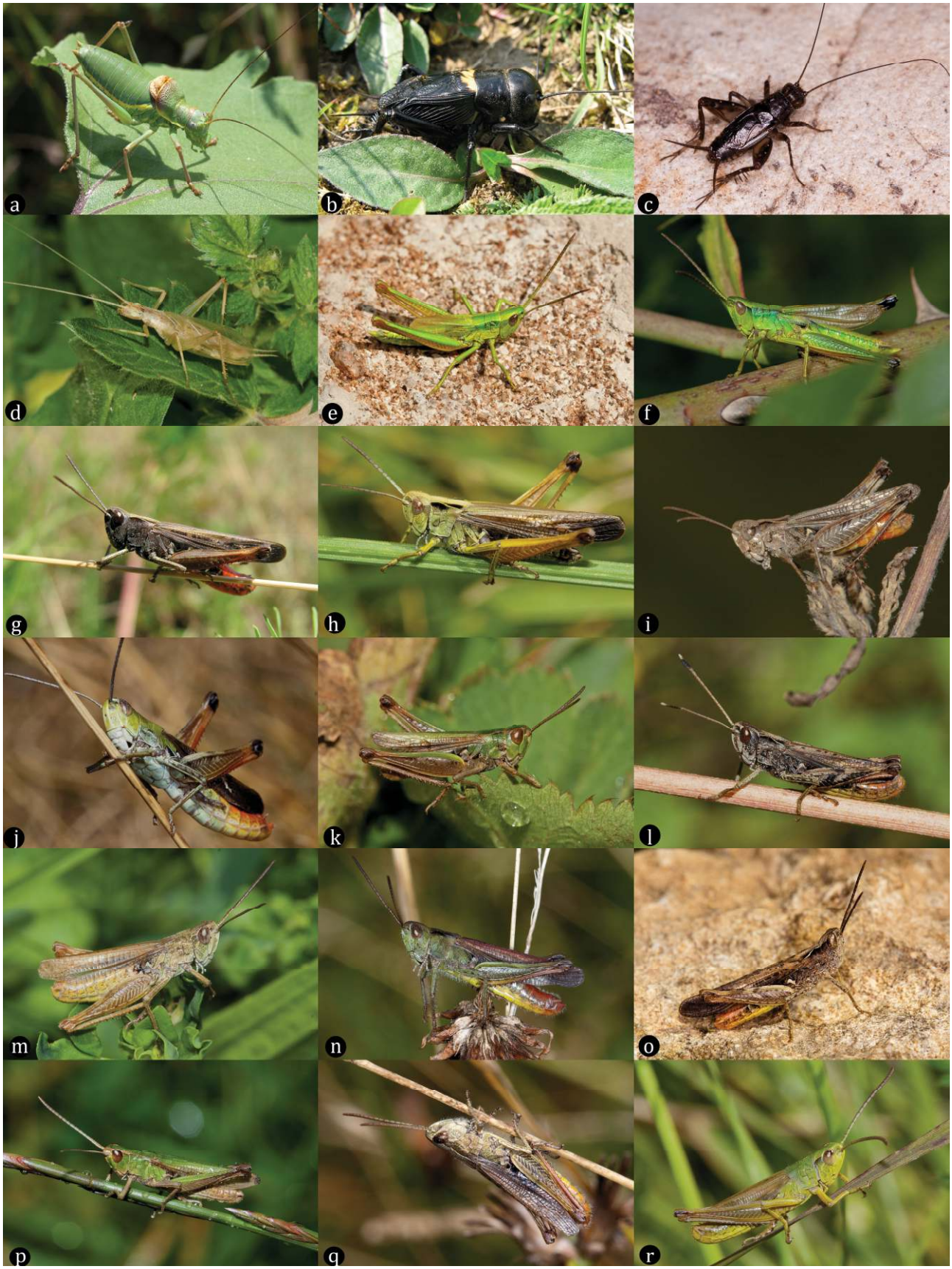


Fig. 9. Photos of studied Orthoptera species (I)



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