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Isophya nagyi, a new phaneropterid bush-cricket (Orthoptera: Tettigonioidea) from the Eastern Carpathians (Caliman Mountains, North Romania)

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Abstract

This study describes *Isophya nagyi* sp. n. from the Caliman Mountains (Eastern Carpathians, Romania). This species was discovered on the basis of the special rhythmic pattern of its male calling song. Regarding morphology *Isophya nagyi* is similar to the species of the *Isophya camptoxypha* species-group (*I. ciucasi, I. sicula, I. posthumoidalis, I. camptoxypha*), however the male stridulatory file contains more stridulatory pegs (105–130) compared to the other members of the species group (50–80 pegs). Calling males produce a long sequence of evenly repeated syllables (repetition rate varies between 60–80 syllables at 21–24 ºC), and most importantly syllables are composed of three characteristic impulse groups contrary to songs of the other species where syllables are composed of two elements or the song consists of two syllable types. Besides the description of the basic morphological features and pair-forming acoustic signals of the new species, a calling song based key is given for the *I. camptoxypha* species group.

Key words: oscillogram, spectrogram, male calling song, female reply latency, stridulatory file

Introduction

The morphology-based species level identification of specimens is often a desperately hard work in the genus *Isophya* Brunner von Wattenwyl 1878, because of very high species richness (Eades et al. 2012), the low level of morphological diversity and the lack of the sclerotised internal genitals in males (Heller et al. 2004). In males generally the fore wing and cerci bear the most useful morphological characters, in females the shape and size of ovipositor are the most widely used in species identification. However, the most efficacious and reliable way to recognize *Isophya* species is to examine the amplitude modulation pattern of the males' species specific acoustic signals (e.g. Heller 1988; Orci et al. 2010). These are the main reasons for the relative high number of species which have been described in the last decade (e.g. Sevgili & Heller 2003; Sevgili et al. 2006; 2012; Chladek 2007; Iorgu and Iorgu 2010; Ingrisch & Pavicevic 2010; Orci et al 2010). The diversity centre of the genus is considered to be in Anatolia (La Greca 1999), but in the Eastern Balkans and in the Carpathian Mountains there are also several *Isophya* species with rather restricted distribution areas (Heller et al. 2004; Nagy 2005; Iorgu et al. 2008).

The Romanian *Isophya* fauna is relatively rich, it counts presently 17 species. Four of them are known to be endemic for some territories of Romania and three of these (*I. harzi* Kis 1960, *I. sicula* Orci, Szövényi & Nagy 2010 and *I. ciucasi* Iorgu & Iorgu 2010) are distributed in different parts of the Carpathian Mountains. The very recent discovery of the two latter new and morphologically cryptic species (Orci et al. 2010; Iorgu & Iorgu 2010) shows well, that the indication of Heller et al. (2004) was right on the possible presence of yet not known species of this genus in the Carpathian Mountains. A new species of this group is described here from the Eastern Carpathian highlands.

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Materials and methods

We discovered the first specimens of the new *Isophya* species, *Isophya nagyi* sp. n. at the western slope of Mt. Iezerul Călimanului (Căliman Izvor, Spring of Caliman) on 27th July 2011 during a short excursion in the Caliman Mountains situated in the middle part of the Eastern Carpathians. At that time most specimens were adult and only few of them were last instar nymphs. Numerous adult specimens could easily be detected on leaves of *Rubus idaeus* and *Rumex alpinus* bushes in forest clearings and subalpine meadows.

Bioacoustic examination

The calling song of 10 males were recorded and analysed. Female response song could be examined only in 2 females. Song recordings were made using the following equipment: condenser microphones (Brüel&Kjaer type 4194 and 4939) connected to a NI USB 6211 DAQ card through a Nexus signal conditioning amplifier; or with a solid-state recorder, M-Audio MicroTrack II 24/96 with its “T”-shaped accessory microphone, or with an other solid-state recorder Zoom H2 with its built in stereo microphone, or with a Sony high density MiniDisc recorder (MZ-RH10) capable of recording to losses, uncompressed sound files with a Sure BG 4.0 condenser microphone. PC recording was made using the software Avisoft Recorder, oscillographic and spectrographic analyses were made using the software Avisoft SASLab pro and Adobe Audition 1.5. During recordings 200 kHz, 96 kHz, 44.1 kHz sampling frequency and 24 or 16 bit amplitude resolution were applied depending on the capability of the equipment used.

Bioacoustic terminology

The bioacoustic terminology of this study is adopted mainly from Ragge and Reynolds (1998).

Calling song: spontaneous song produced by an isolated male.

Syllable: the song produced by one opening-closing movement cycle of the tegmina.

Impulse: a simple undivided transient train of sound waves (here: the highly damped sound impulse arising as the impact of one tooth of the stridulatory file).

Click: an isolated distinct impulse.

Functional unit of the song: the shortest part of the song, which contains all necessary song elements and in the appropriate order to elicit female response.

In this study the movement of tegmina during stridulation was observed by our unaided eyes, therefore very fast movements may not be detected by us, and thus the song units here described as syllables may be produced by more complex movements and may turn out to be fast syllable groups after a thorough examination of stridulatory movements with a device providing fine time resolution oscillograms of tegminal movements (Helversen & Elsner 1977). However our observations suggest that the song unit we describe here as syllables are really the product of one opening-closing wing movement cycle.

Song characters measured

The acoustic signals of European Orthoptera are generally amplitude modulated signals (Heller 1988; Ragge & Reynolds 1998) therefore we focused on rhythmic characters which can be measured precisely on oscillograms. We chose characters that seems to contribute significantly to the general appearance of the signal, and which may be useful when comparing it to the song of other congeneric species. The following oscillographic characters were measured: duration of A-element (DA), duration of B-element (DB), duration of C-element (DC), number of impulses in A-element (NIA), number of impulses in B-element (NIB), number of impulses in C-element (NIC), silent interval between A- and B-element (IntAB), silent interval between B- and C-element (IntBC), silent interval between C-element and A-element of the next syllable (IntCA). Measurement points of those characters can be seen in Fig. 1.

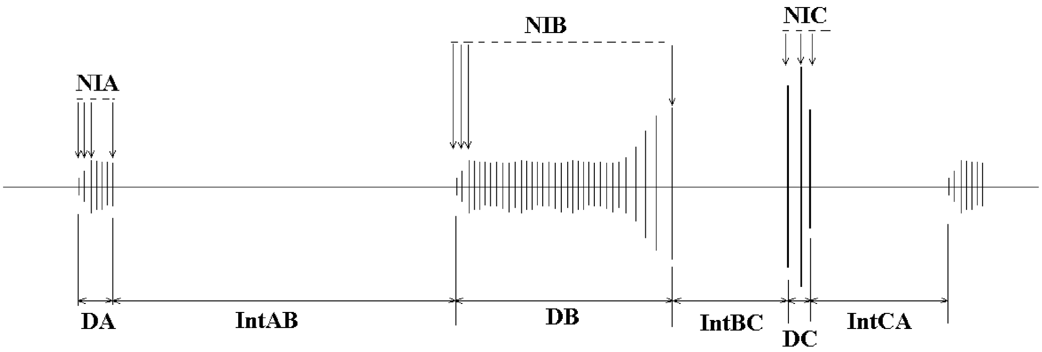

FIGURE 1. A schematic oscillogram of the male calling song of *I. nagyi* sp. n. showing the measurement points of the examined song characters.

Morphometric examination

Morphological measurements were made in 20 males and 13 females with a stereomicroscope (Zeiss–Jena GSZ) equipped with an ocular micrometer. A description of the examined morphometric characters can be found in Orci et al. 2005 with a schematic drawing of the main measurement points used.

Isophya nagyi Szövényi, Puskás & Orci, sp. n.

Type material and depository:
Holotype: male specimen in ethanol, Romania, Suceava County, Caliman Mts., 6.5 km south of Gura Haitii, subalpine meadow on the west slope of Mt. Iezerul Călimanului, 1580 m a.s.l., N 47.141° E 25.267°, leg. K.M. Orci, G. Puskás & G. Szövényi, 27.07.2011; appended with a CD containing a sound recording of its calling song.

Allotype: female specimen in ethanol, same data as in holotype.

Paratypes: 17 males (3 of them dry pinned, the others preserved in ethanol), 11 females (all in ethanol) with the same data as in holotype; 11 males (6 of them dry pinned, 5 in alcohol) and 1 female (in ethanol), Romania, Suceava County, Caliman Mts., 7 km south of Gura Haitii, forest clearing on the west slope of Mt. Iezerul Călimanului, 1340 m a.s.l., N 47.137° E 25.256°, leg. K.M. Orci, G. Puskás & G. Szövényi, 27.07.2011.

Holotype, allotype, 23 male and 9 female paratypes are deposited in Collection of smaller insect orders, Department of Zoology, Hungarian Natural History Museum, Budapest, Hungary; 5 male and 3 female paratypes in collection of G. Szövényi.

Description of the acoustic signals used during pair-formation.

Male calling song
The male calling song is a long syllable sequence of indefinite duration (however males often produce short sequences composed of 4–10 syllables). Syllable repetition rate is 60–80 syllables/minute at 21–24 ºC. The song is composed from one syllable type (Fig. 2/A–C). Mean duration of syllables varied between 570–820 ms in the 10 examined males (overall mean was 697.3 ms, N=10, standard deviation 92.2 ms). Typically each syllable is composed of three, consecutive impulse series referred to as impulse series A, B and C. Each impulse series has a characteristic amplitude modulation pattern. The first series (impulse series A) is a small group of low-amplitude impulses (see the first dashed line box in Fig. 2/A). It is followed by the long B impulse series, which shows generally an intensive crescendo at its end, where impulse repetition rate decreases noticeably (Fig. 2/A: second box). After a short silent interval the syllable is terminated by a short group of large amplitude impulses (series C; Fig. 2/A: third box). Besides that typical syllable structure some of the examined males tended to produced

syllables with irregular oscillographic patterns at the beginning of their songs. For detailed descriptive statistics of the examined song characters (Fig. 1.) see Tab. 1.

TABLE 1. Mean values of the examined calling song parameters for each examined male specimens, and their overall descriptive statistics for all the ten examined specimens (for the abbreviations of song parameters see Fig. 1 and the text of Materials and Methods). Ambient air temperature during the sound-recording in °C is also included for each male. Duration values are given in milliseconds.

male	DA	NIA	IntAB	DB	NIB	IntBC	DC	NIC	IntCA	Temp.
#1	33.2	17	317.9	214.1	79	54.2	1.7	1.8	125.8	22.5
#2	15.4	4.4	420.6	207.3	60.2	72.9	2.3	1.9	148	21.2
#3	34.9	17.6	392	217.8	49.5	55.8	5.4	2.8	121.2	22.8
#4	24.5	6.5	483.6	215.4	70.1	83.2	3.9	3.2	148.9	22.4
#5	42.7	17.2	492.6	217	58.9	61.7	4.6	3.4	156.9	22.8
#6	31.4	18.2	401.9	179.5	49	91.5	5.4	4	227.9	22.1
#7	7	3.4	347.7	189.8	53.8	74.5	5.4	3.3	176.6	23.7
#8	36.2	22.3	576.9	129.5	38.7	56.4	1	1	126.5	24
#9	41	26.6	316.7	142.3	41.9	72	2.8	1.6	172.8	24
#10	39.4	16.3	297.9	176.9	67.2	72.1	3.4	3	197.8	24
Mean	30.57	14.95	404.78	188.96	56.83	69.43	3.59	2.6	160.24	22.95
S.D.	11.61	7.71	90.65	32.03	12.77	12.36	1.62	0.96	34.24	0.95
Minimum	7	3.4	297.9	129.5	38.7	54.2	1	1	121.2	21.2
Maximum	42.7	26.6	576.9	217.8	79	91.5	5.4	4	227.9	24

The male calling song has its dominant frequency components in the ultrasonic range, between 20 kHz–28 kHz, however frequency components of lower amplitude can be detected between 10 kHz and 50 kHz (Fig. 3).

Females respond to the males' calling song emitting simple clicks (or short groups of clicks) after the C impulse series of the male during the C–A silent interval (Fig. 2/D). The latency of reply clicks was 71–127 ms from the beginning of the males' C impulse series in the two examined females (mean reply latency was 112.2 (n=5) and 83.2 ms (n=9) respectively, at ambient air temperature 22.1 ºC).

Morphology

Male (Fig. 4/A–D, Fig. 5/A, G, H, Fig. 6/A, B)

Head with fastigium verticis at base nearly as wide as half of scapus, relatively prolonged, slightly tapered frontward; with pronounced dorsal sulcus.

Pronotum 3.3–4.3 mm long, lateral carinae parallel in prozona, broken at traverse sulcus, considerably widen at the middle of length of metazona and becomes parallel or at the end slightly narrows in the posterior half of metazona; anterior and posterior edges of pronotum concave; in lateral view, dorsal surface of pronotum concave, raised in metazona; ventral edge of paranota nearly straight; caudal margin of paranota straight or slightly curved and passing into the hind margin of pronotum. Maximum height of paranota about half the length of pronotum.

Elytra somewhat longer than pronotum, reaching anterior third of 2^{nd} abdominal tergite. Cubitus2 of tegmen swollen, its length 3/4–4/5 of width of pronotum's caudal margin, nearly reaching the right margin of tegmen, angle between cubital veins of about 65–80°, mirror large and quadrangular. Right margin of left tegmen forms an about 110° angle at the distal end of Cu2.

Stridulatory file arcuate and 2.45–2.7 mm in length (n=8), with 105–130 teeth (n=9) (Fig. 5 A).

Hind femur 3.6–4.6 times long as pronotum, without ventral spines.

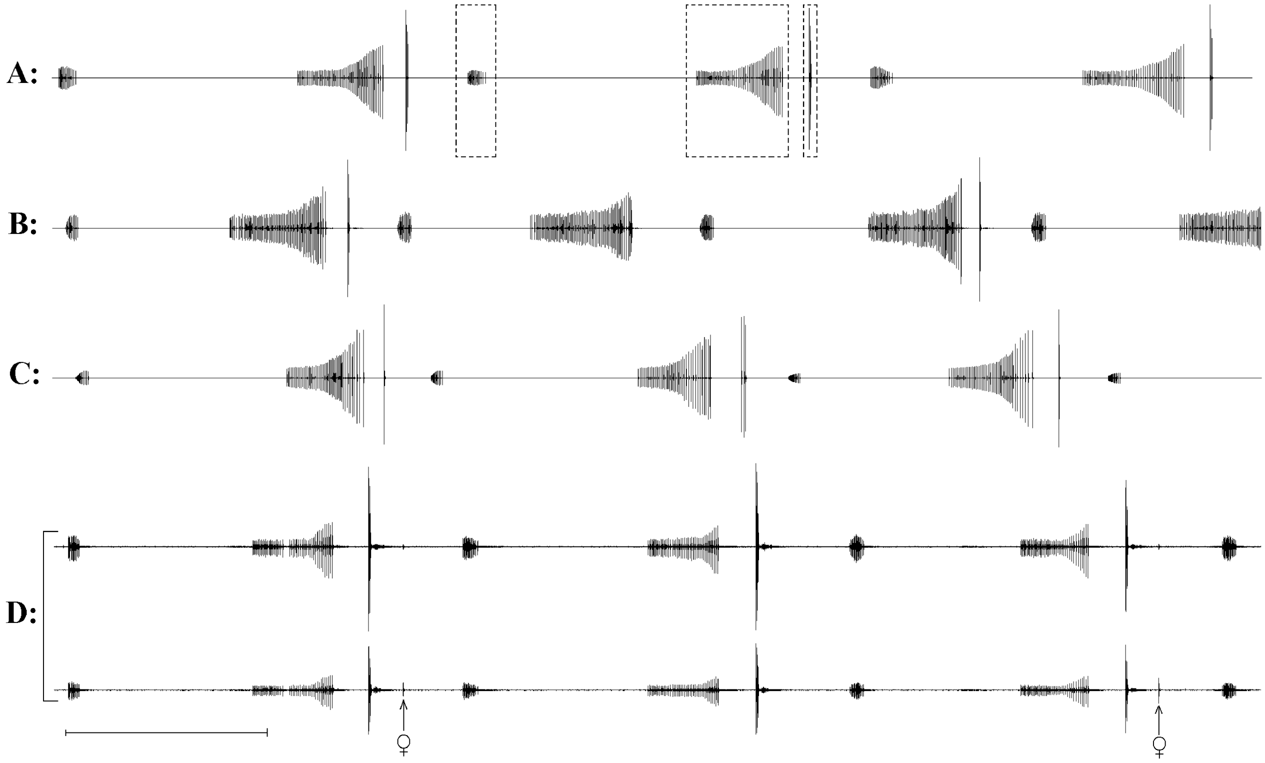

FIGURE 2. Oscillograms of the calling songs of three males (A, B, C) of *I. nagyi* sp. n. and a two-traced oscillogram of the male-female duet showing the timing of female response clicks in relation to the male song (D). The three dashed line boxes in (A) show the three consecutive impulse groups of one syllable (ambient air temperature varied between 22–23 °C during these recordings, time scale is the same for all oscillograms in the figure, the bar under oscillogram D indicates 500 ms).

Cercus 2.2–2.8 mm long, covered by many short hairs, gradually narrows distalwards, distal 2/5 gradually and moderately incurved, apex of cercus in dorsal view tapered into one strong, triangular shaped, black apical spine of relatively wide base.

Subgenital plate moderately elongated, reaching the 2/3–3/4 length of cerci in dorsal view, narrowed apically with a "v" or "u" shaped incision and more or less acute lobes on its caudal margin.

Coloration green with small darker spots with two parallel lighter green stripes on dorsal side of pronotum, in less than 10% of the examined specimens with two orange or red bilateral stripes on dorsal side from pronotum to the end of abdomen, reddish stripes sometimes combined with white and/or black margins. Antennae yellowish brown, fastigium greenish brown, disc of pronotum green, lateral carinae with narrow white stripes in its whole length complemented by reddish brown stripe in metazona. Tegmina brownish with light brown costal field and green margins with light yellowish lateral stripe. Legs greenish or brownish sometimes with small darker spots.

For descriptive statistics of morphometric characters examined in males see Tab. 2.

Female (Fig. 4/E–H, Fig. 5/F)

Head roughly as in male but somewhat bigger.

Pronotum 4.4–5 mm long, with straight lateral carinae, dorsal surface slightly concave, caudally widening from the moderately concave frontal margin until its similar caudal margin; with shallow sulcus, paranota similar to those of male.

Tegmina about third the length of pronotum, approaching or reaching the anterior margin of 1st abdominal tergite, roughly quadrangular, edges more or less rounded. Right tegmen with two variable fields of stridulatory bristles on its dorsal surface near inner margin.

Hind femur 3–3.5 times as long as pronotum, without ventral spines. Epiproct semicircular. Cerci short, 1.3–1.6 mm long, covered by short hairs, slightly bent, spine-like shaped.

Subgenital plate rounded, triangular like. Ovipositor relatively short (8.3–9.8 mm), 1.9–2 times as long as pronotum, gradually curving distalwards; with 8–12 acute spines on dorsal and 7–11 on ventral margin, gonangulum ellipsoid.

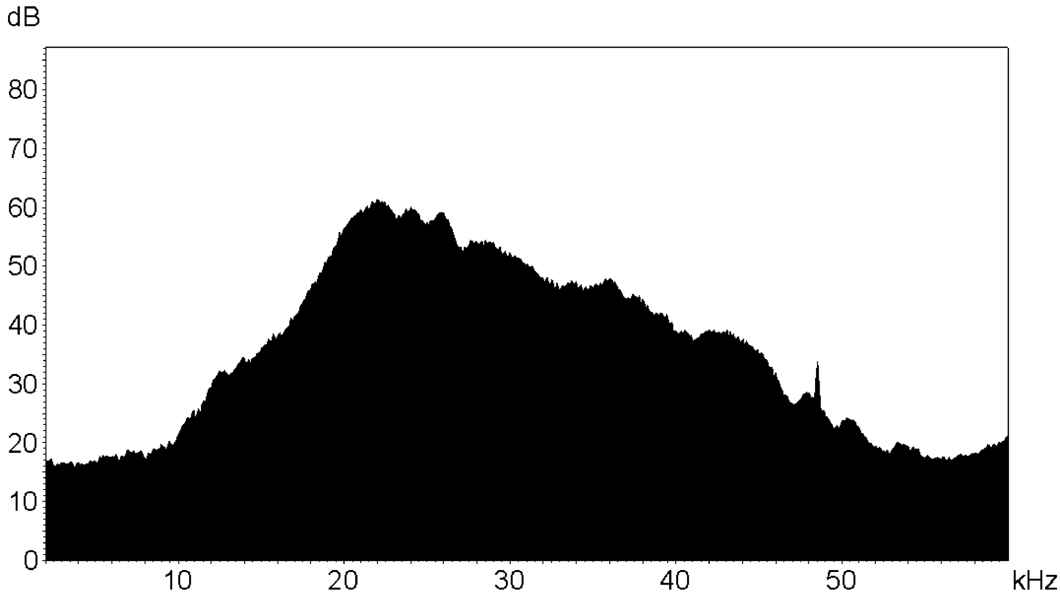

FIGURE 3. Power spectrum of the male calling song of *I. nagyi* sp. n. (recording distance approx. 15 cm, 2024 piont FFT analysis with Blackmann window function).

TABLE 2. Descriptive statistics of some morphometric characters of *Isophya nagyi* sp. n. males (in millimetres).

	Mean	**Minimum**	**Maximum**	**S.D.**	**N**
Width of head	3.64	3.4	3.8	0.105	20
Length of pronotum	3.84	3.3	4.3	0.261	20
Width of pronotum (frontally)	3.19	3	3.6	0.159	20
Width of pronotum (caudally)	4.6	4.4	5.2	0.201	20
Length of left elytrum	4.44	4	4.8	0.211	20
Width of left elytrum	4.1	3.8	4.4	0.16	20
Length of stridulatory file	2.57	2.45	2.7	0.085	8
Number of stridulatory pegs	115.33	105	130	8.11	9
Length of hind femur	15.58	14.3	16.8	0.747	20
Length of cercus	2.54	2.2	2.8	0.131	20

Coloration of head, body and legs similar to that of male. Tegmina greenish with brownish inner and light yellowish lateral edges. Ovipositor greenish with darker spots, its spines dark brown.

For descriptive statistics of morphometric characters examined in females see Tab. 3.

Diagnosis

Male song is a long sequence of syllables repeated evenly at a rate of 60–80 syllables per minute at 21–24 °C ambient air temperature. Syllable duration varies between 570–820 ms (mean value for specimens at 21–24 ºC). Syllables are composed of three groups of impulses as in the oscillograms of Fig. 2. Female response clicks are produced between the C and A impulse group of the male song (Fig. 2/D) and have a reply latency of 50–150 ms (measured from the beginning of C impulse group, at 24–25 °C). Fastigium verticis at base nearly half as wide as scapus. Tegmina relatively short in male, reaching anterior third of 2nd abdominal tergite, the length of Cu2 3/4–4/5 of the width of caudal margin of pronotum, right margin of left tegmen with a rounded obtuse angle about 110° at the distal end of Cu2, 2.45–2.7 mm long stridulatory file contains 105–130 pegs. Cerci of male 2.2–2.8 mm long, gradually narrow distalwards, distal 2/5 gradually and moderately incurved, apex tapered into 1 strong, triangular shaped, black apical spine of relatively wide base. Ovipositor 8.3–9.8 mm long.

TABLE 3. Descriptive statistics of some morphometric characters of *Isophya nagyi* sp. n. females (in millimetres).

	Mean	Minimum	Maximum	S.D.	N
Width of head	4.04	3.9	4.2	0.1	13
Length of pronotum	4.64	4.4	5	0.206	13
Width of pronotum (frontally)	3.43	3.21	3.7	0.144	13
Width of pronotum (caudally)	4.85	4.5	5.1	0.176	13
Length of left elytrum	1.65	1.3	2	0.226	13
Length of subgenital plate	1.2	1.1	1.3	0.082	13
Width of subgenital plate	3.29	3	3.6	0.18	13
Length of hind femur	15.23	14.4	16.1	0.618	13
Length of ovipositor	9.22	8.5	9.8	0.383	13
Narrowest width of ovipositor	2	1.85	2.1	0.079	13
Length of body	24	21.3	26.4	1.758	13
Length of left cercus	1.43	1.3	1.6	0.103	13

Etymology

The authors name this new species after their mentor Barnabás Nagy (Plant Protection Institute of Hungarian Academy of Sciences, Budapest), a senior Hungarian orthopterologist, who is always ready to help their work sharing his knowledge gathered during decades of orthopterological research, and who contributed so much to their knowledge on the *Isophya* species living in the Carpathians and Carpathian Basin.

Habitat and distribution

Until now the new species is known only from the type locality, the huge and eroded volcanic caldera of the Mountain Range of Caliman. A relatively large and dense population of the newly discovered bush cricket has been found on western slopes (between 1300 and 1650 m a.s.l.) of the peak Iezerul Călimanului at the southern edge of Suceava county. Here they inhabit shrubs growing in spruce forest clear cuts, and old subalpine meadows rich in dicotyledonous herbs (Fig. 6/C, D).

Discussion

Studying sexual acoustic/vibratory signals has led to the discovery of a huge number of insect species during the last few decades (e.g. Henry 1994; Walker et al. 2003; Sueur & Puissant 2007; Iorgu & Iorgu 2010; Ferreira et al. 2010) as the use of bioacoustic methods in taxonomy became more intensive (Sueur 2006). The present recognition of *I. nagyi* as a new species is also based mainly on its distinctive acoustic signals. This new species shows affinities to two species groups of *Isophya*. One of those is a group of species which we propose to call the *I. camptoxypha* species group (see its description below) containing species related morphologically rather closely to *I. nagyi*, the other is the *I. amplipennis* species group (Ünal 2010) in which some of the species show similarities in morphology others produce calling songs with similar oscillographic structure. Presently the *I. camptoxypha* group contains the following 5 species: *Isophya nagyi*, *I. ciucasi*, *I. sicula*, *I. posthumoidalis* and *I. camptoxypha*. All these species are rather similar to each other in morphology (compare the results presented in Heller et al. 2004, Orci et al. 2010, Iorgu and Iorgu 2010) and share the following combination of morphological characters: fastigium verticis half as wide as scapus or narrower, left tegmen in male narrower or maximum as wide as the caudal margin of pronotum, right margin of left tegmen turns in a rounded angle at the distal end of Cu2 (vena bearing the stridulatory file), male cerci short, show a continuous curvature at their apical third and each has one black denticle at the apex, apex cerci blunt or gradually tapering, ovipositor is short (6.5–10 mm). Within the *I. camptoxypha* group *I. nagyi* can be recognized with high confidence examining the stridulatory file of the males which bears 105–130 pegs, in contrast to the 50–80 pegs of the other 4 species. Sensu lato all these species may be regarded as members of a larger, more heterogeneous set of species the *I. pyrenea* species group described by Warchalowska-Sliva et al. (2008), but within that set of species the *I. campoxypha* species group forms a rather compact group differing strongly from all the other members of *I. pyrenea group* (*I. altaica, I. gulae, I. obtusa, I. pyrenea*).

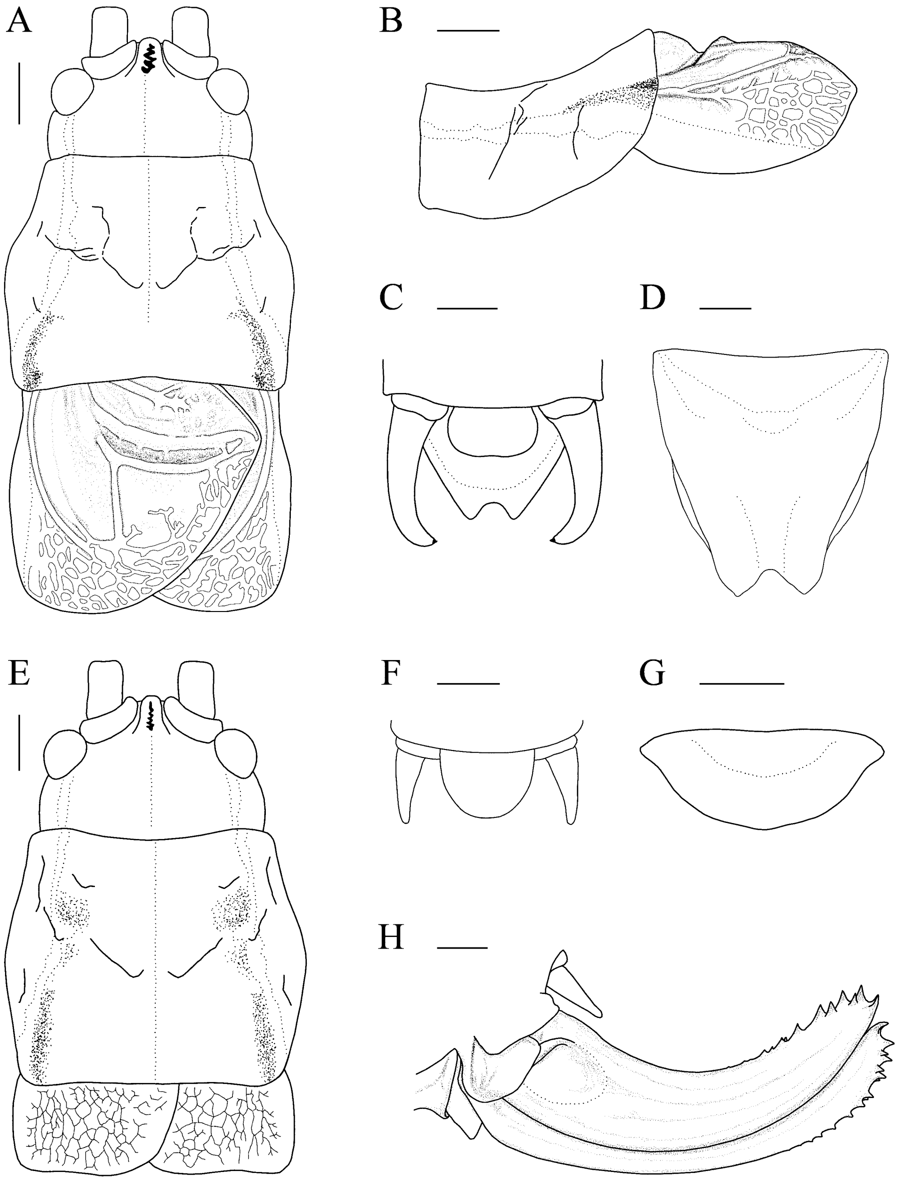

FIGURE 4. Drawings illustrating the typical eidonomy of *Isophya nagyi* sp. n. male (A–D) and female (E–H). A, E, head, pronotum and tegmina in dorsal view; B, pronotum and tegmina in lateral view; C, F, abdominal apex in dorsal view; D, G, subgenital plate; H, ovipositor. Bars indicate 1 mm.

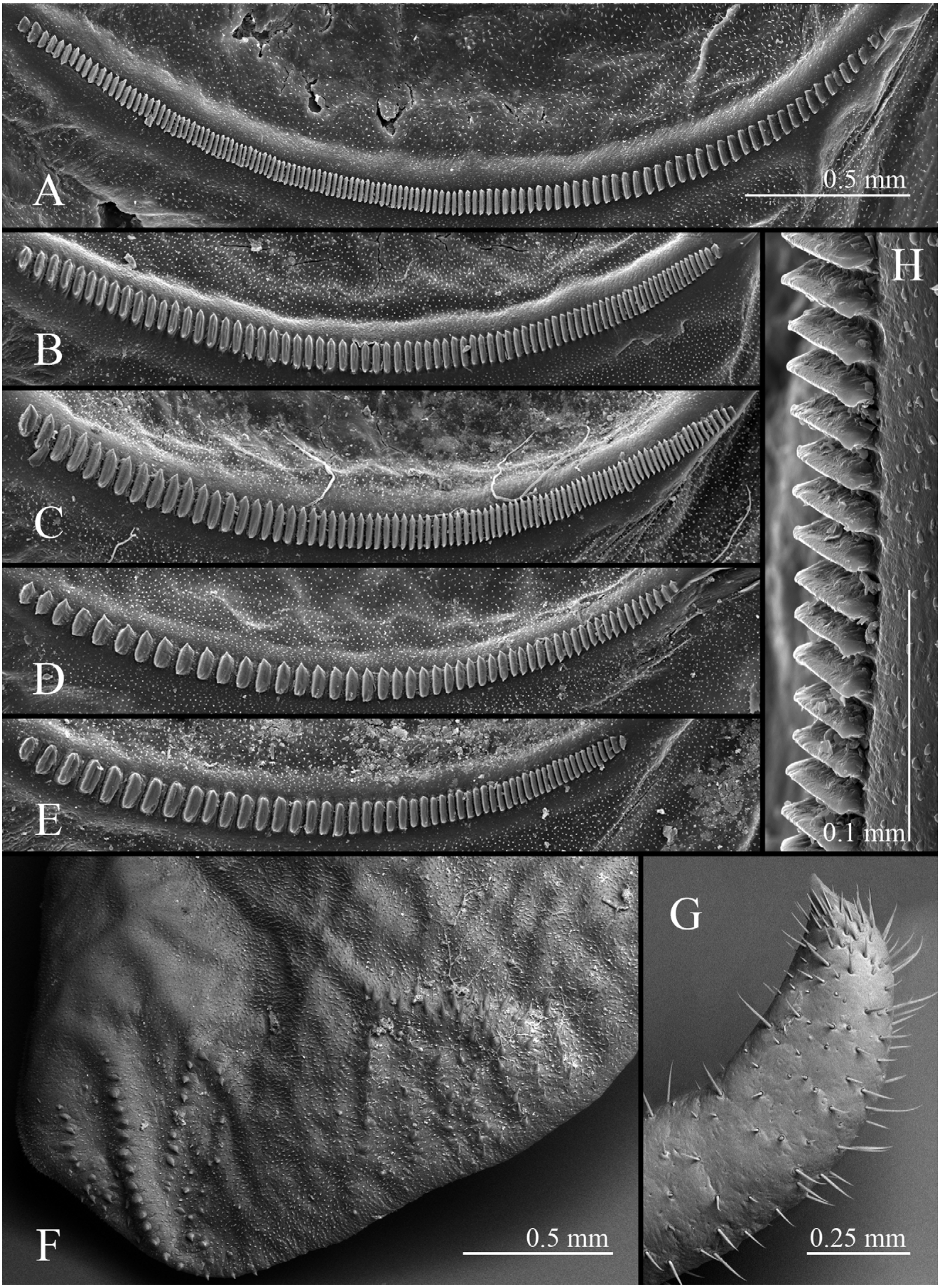

FIGURE 5. SEM photos of the male stridulatory file of *Isophya camptoxypha* species group (A–E), stridulatory bristles of the inner quartile of female right tegmen (F), distal third of male left cercus (G) and mid part of male stridulatory file (H). A, F–H, *I. nagyi* sp. n.; B, *I. camptoxypha*; C, *I. ciucasi*; D, *I. posthumoidalis*; E, *I. sicula*. Scale is the same for A–E, but different in F–H.

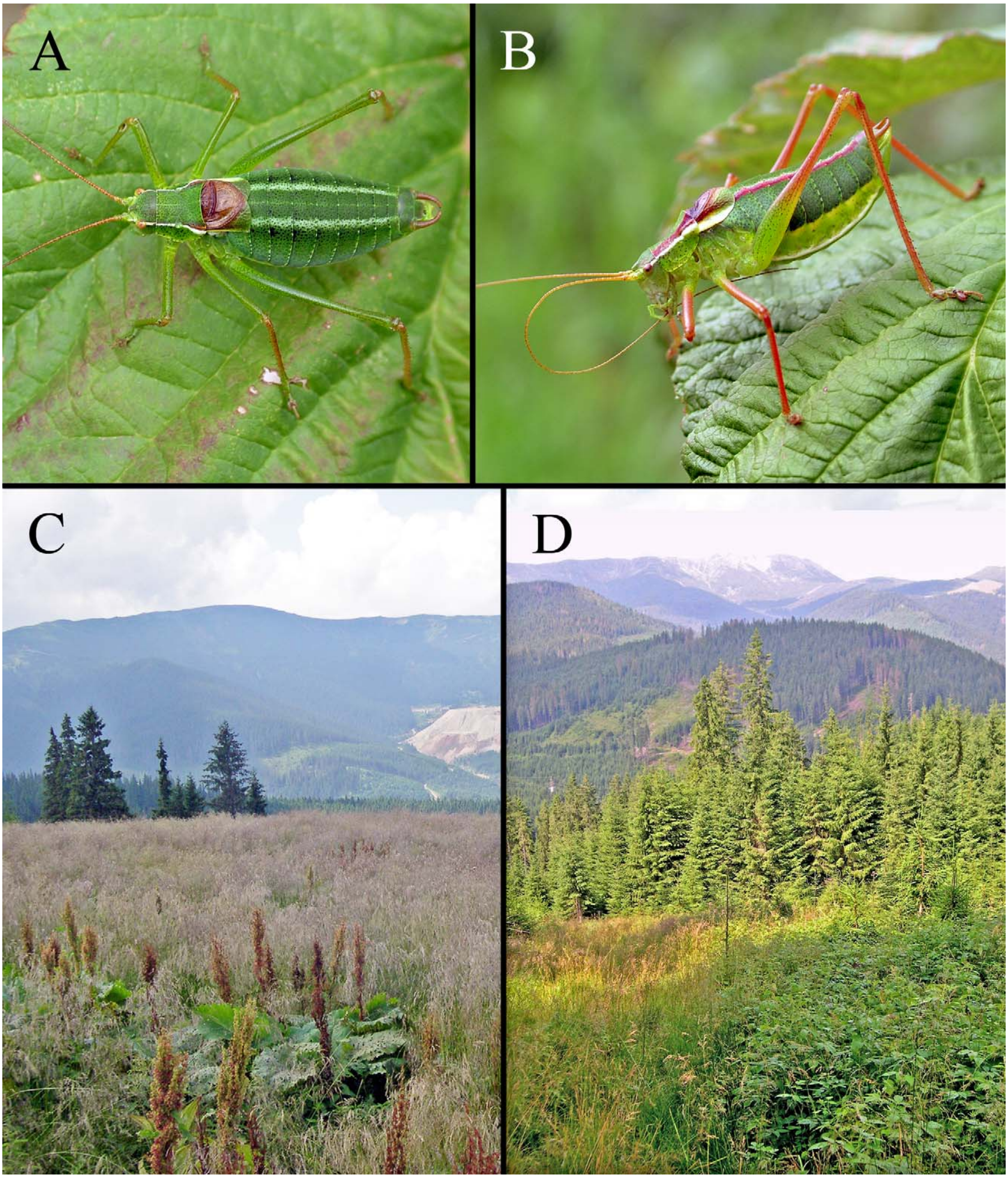

FIGURE 6. Photos of normal coloured (A) and red striped (B) specimens of *Isophya nagyi* sp. n. and its habitats on Mountain Izvor Caliman at 1400 m (D) and 1600 m (C) a.s.l in July, 2011.

Some other related species can be found in the *I. amplipennis* group (Ünal 2010; Sevgili et al. 2012), where most of the species are rather different from *I. nagyi* in morphology and occupies areas in the European part of Turkey and in the Middle East, quite distant from the area of *I. nagyi* (Eastern Carpathians) except from *I. speciosa*, which reaches the south eastern part of Carpathian Basin. On the other hand two of them, *I. gracilis* and *I. savignyi*, produce calling songs which shows the highest resemblance to the song of *I. nagyi* (amongst the species where we have published information about the male's acoustic signals). Males of both species produce a crescending basic song element divided into two (*I. gracilis*, see Zhantiev and Dubrovin (1977)) or three components (*I. savignyi*, see

Heller (1990) and song samples in the DORSA data base). But the group of high-amplitude clicks (element C *in I. nagyi*) is missing in both *I. gracilis* and in *I. savignyi* and the repetition rate of the basic song element is much slower (c. a. 3 per minute in *I. gracilis* (Zhantiev & Dubrovin 1977), and c. a. 7–10 per minute in *I. savignyi* (as measured on issa8501.wav (temperature 20 ºC) in DORSA)) than in *I. nagyi*. Both of those species has wider tegmina in males (the right edge of left tegmen projects clearly over the right margin of right tegmen) and thus easily separable from the *I. camptoxypha* group.

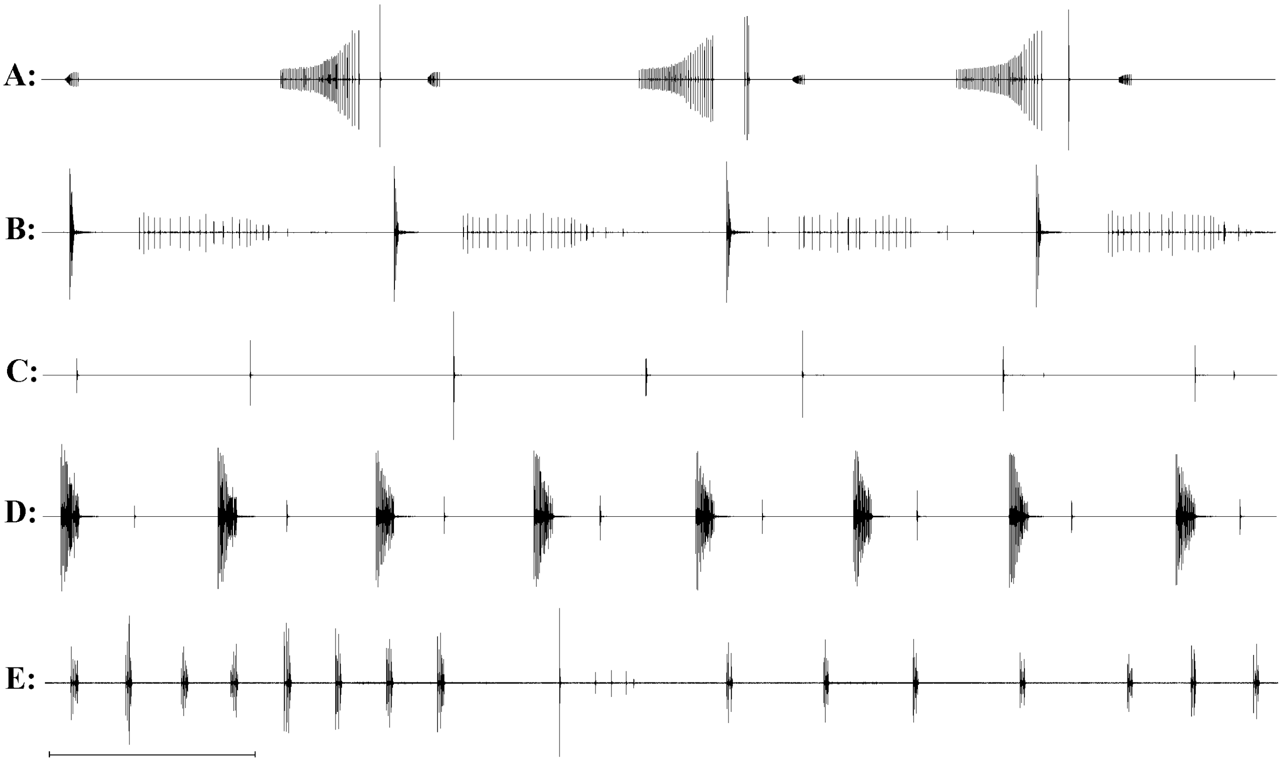

FIGURE 7. Oscillograms of male calling song of the morphologically most closely related species (*I. camptoxypha* species-group). A, *I. nagyi* sp. n. (Munti Calimani, Romania, date recorded 29.07.2011., 22.8 °C), B, *I. ciucasi* (Munti Ciucas, Romania, date 09.08.2006, 22.7 °C), C, *I. sicula* (Munti Harghita-Ciceu, Romania, date 21.07.2005., 24 °C); D, *I. camptoxypha* (Mecsek Mountains, SW Hungary, date 11.06.2008., 23 °C); E, *I. posthumoidalis* (Depresiunea Maramuresului, Romania, date 11.07.2005, 22.3 °C) (time scale is the same for all oscillograms in the figure, the bar under oscillogram E indicates 500 ms).

The *I. camptoxypha* group contains Central and Eastern European species with distribution areas laying near to each other, or possibly overlapping each other (Heller et al 2004, Kenyeres & Bauer 2005; Orci et al. 2010; Iorgu & Iorgu 2010). Therefore we think that the following acoustic signal based identification key will be useful to help the identification of populations:

1a	Male calling song is composed of one type of syllable, syllable repetition is even during undisturbed singing	2
1b	Male calling song is composed of two types of syllable, syllable repetition is regularly uneven, syllable-groups can be recognized in the song (Fig. 7/E).	*Isophya posthumoidalis*
2a	Main impulse series of the syllables are followed by a series of clicks (containing generally more than 5 clicks) (Fig. 7/B) . . .	*I. ciucasi*
2b	Generally less than 5 after-clicks per syllable are produced.	3
3a	Main impulse series of syllables with more than 5 impulses	4
3b	Main impulse “series” of the syllables has less than 5 impulses (generally 1–2 impulses) (Fig. 7/C).	*I. sicula*
4a	Syllables are composed of a continuous main impulse series and some (1–3) additional after clicks (Fig. 7/D) .	*I. camptoxypha*
4b	Syllables are composed of three elements: a short impulse series followed by a longer, crescending impulse series, and followed by some large amplitude, terminal clicks (Fig. 7/A)	*I. nagyi*

The overall shape of amplitude envelope of the male syllables of *I. nagyi* shows principally a crescending pattern interrupted by silent intervals. Simple, crescending-type syllables (without interrupting silent intervals) occur in several groups of Phaneropterinae and that pattern is thought to be the ancestral syllable pattern in this taxon (Heller 1990). So it is plausible to presume that the song pattern of *I. nagyi* evolved from that ancestral crescending syllable type after the addition of two characteristic silent gaps. Those gaps may serve to help the singing male to listen to its environment (e.g. for the acoustic signals of conspecifics or the acoustic cues indicating the presence of predators). An other possible advantage of adding those gaps may be that the duration and complexity of male signal can be increased without much costs (energy expenditure, morphology of stridulatory organs), and both of those characters are often under sexual selection, females preferring longer and more complex calls (Helversen & Helversen 1994; Bailey 2003). Those assumptions could be examined with playback experiments.

The delay of female response varied between 70–130 ms. Considering that the duration of male syllable varied around 700 ms the latency of female reply is in good accordance with the trend published by Bailey and Hammond (2003) showing a positive correlation between female reply latency and male syllable duration. The C element of the syllable, with its short duration and high peak amplitude, is a good candidate to function as a trigger for the female reply. Our data are not appropriate to examine that presumption, but subsequent studies could clarify that question examining the effects of male song modifications on the timing of female response during playback tests.

The distribution pattern of the *I. camptoxypha* species group rises some questions in relation to that of *I. nagyi*. The widest geographical range in this group is known for *I. camptoxypha*, the area of that species streches from Eastern Alps and Prealps in Austria (Zuna-Kratky et al. 2009), to the northern, eastern and southern chains of Carpathians from Poland to Romania and some mountainous and hilly ranges in Transdanubia and Transylvania in the Carpathian Basin (Heller et al. 2004). *I. posthumoidalis* has the second largest area occurring from south eastern Poland to Romania (Heller et al 2004; Szövényi & Orci 2008) however its range seems to be limited to some mountain ranges and small, internal basins of the Carpathians. The ranges covered by the two recently discovered species in this group are less known. Both were described form very restricted areas in the Romanian Carpathians. Until now *I. ciucasi* is known to be distributed only in a small part of Ciucas Mountains (the type locality, see Iorgu & Iorgu 2010), however *I. sicula* which was believed to be restricted to the Harghita Ciceu mountain and maybe the neighbouring peaks of Harghita Mountains, was surprisingly discovered in the Moldavian Subcarpathians, about 100 km north eastward from its type locality (Iorgu 2011). Until now *Isophya nagyi* is known only from the type locality, its range is presumably covers similar habitats in the Caliman Mountains, or at least in its eastern part. Since its known habitats showed no apparent special features we can not exclude the possibility of even a wider distribution in the Eastern Carpathians.

The present study gives a first characterisation of the bioacoustics and morphology of *I. nagyi*, and the information presented here can be useful for the identification and acoustic detection of this species during subsequent studies. However many interesting aspects of the biology of this new species wait for exploration. First of all to understand more about the evolution of this species a molecular phylogenetic analysis will be necessary involving at least members of the *I. camptoxypha* and *I. amplipennis* species groups. Moreover with its relatively complicated male calling song the species may be an interesting object for studying acoustic signal based species recognition and sexual selection.

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References

Bailey, W.J. (2003) Insect duets: underlying mechanisms and their evolution. *Physiological Entomology*, 28, 157–174.

Bailey, W.J. & Hammond, T.J. (2003) Duetting innsects—does call length influence reply latency? *Journal of Zoology*, 260, 267–274.

Chladek, F. (2007) *Isophya fatrensis* sp.nov. aus der Slowakei (Orthoptera, Ensifera, Phaneropteridae). *Tetrix*, 2(3), 9–12.

DORSA (2012) Digitized Orthoptera Specimens Access. Available from: http://www.dorsa.de (June 2012)

Eades, D.C., Otte D., Cigliano, M.M. & Braun, H. (2012) Orthoptera Species File Online. Version 2.0/4.1.Available from: http://Orthoptera.SpeciesFile.org. (6 Aug. 2012).

Ferreira, R.S., Poteaux, C., Delabie, J.H.C., Fresneau, D. & Rybak, F. (2010) Stridulations Reveal Cryptic Speciation in Neotropical Sympatric Ants. *PLoS ONE*, 5(12), e15363. http://dx.doi.org/10.1371/journal.pone.0015363

Heller, K.-G. (1988) *Bioakustik der europäischen Laubheuschrecken.* Verlag J. Margraf, Weikersheim, 358 pp.

Heller, K.-G. (1990) Evolution of song pattern in East Mediterranean Phaneropterinae. *In*: Bailey W. J. & Rentz D. C. F. (Eds), *The Tettigoniidae: Biology, Systematics, Evolution.* Crawford House Press, Bathurst, pp. 130–151.

Heller, K.-G., Orci, K.M., Grein, G. & Ingrisch, S. (2004) The *Isophya* species of central and western Europe (Orthoptera: Tettigonioidea, Phaneropteridae). *Tijdschrift voor Entomologie*, 147, 237–258.

Helversen, O. von & Elsner, N. (1977) The stridulatory movements of acridid grasshoppers recorded with an opto-electronic device. *Journal of Comparative Physiology (A)*, 122, 53–64.

Helversen, O. von & Helversen, D. von (1994) Forces driving coevolution of song and song recognition in grasshoppers. *In*: Schildberger, K. & Elsner, N. (Eds), *Neural basis of behavioral adaptations.* Gustav Fischer Verlag, Stuttgart, Jena, New York, pp. 253–284.

Henry, C.S. (1994) Singing and cryptic speciation in insects. *Trends in Ecology & Evolution*, 9, 388–392.

Hertach, T. (2011) Spectacular song pattern from the Sicilian Mountains: The new cicada species *Cicadetta anapaistica* sp n. (Hemiptera: Cicadidae). *Zootaxa*, 2771, 25–40.

Ingrisch, S. & Pavicevic, D. (2010) Seven new Tettigoniidae (Orthoptera) and a new Blattellidae (Blattodea) from the Durmitor area of Montenegro with notes on previously known taxa. *Zootaxa*, 2565, 1–41.

Iorgu, I.S. (2011) Bioacustics of two newly recorded bush-crickets in the historical region of Moldavia: *Isophya pienensis* and *Isophya sicula* (Insecta: Orthoptera). *In*: *Actual problems of protection and sustainable use of the animal world diversity.* Academy of Sciences of Moldova, Department of Nature and Life Sciences, Institute of Zoology, Chisinau, pp. 117–119.

Iorgu, I.S., Pisica, E.I., Pais, L., Lupu, G. & Iusan, C. (2008) Checlist of Romanian Orthoptera (Insecta) and their distribution by eco-regions. *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"*, 51, 119–135.

Iorgu, I.S. & Iorgu E.I. (2010) A new species of *Isophya* (Orthoptera:Phaneropteridae) from the Romanian Carpathian Mountains. *Travaux du Muséum d'Histoire Naturelle "Grigore Antipa"*, 53, 161–170.

Kenyeres, Z. & Bauer, N. (2005) Untersuchung des Lebensraumes von *Isophya camptoxypha* (Fieber, 1853) im Kőszeger Gebirge (Westungarn). *Articulata*, 20(1), 1–15.

La Greca, M. (1999) Il contributo degli Ortotteri (Insecta) alla conoscenza della biogeografia dell' Anatolia: La componente gondwaniana. *Biogeographia*, 20, 179–200.

Nagy, B. (2005) Orthoptera Fauna of the Carpathian Basin—recent status of knowledge and a revised check-list. *Entomofauna Carpathica*, 17, 14–22.

Oci, K.M., Szövényi, G. & Nagy, B. (2010) *Isophya sicula* sp. n. (Orthoptera: Tettigonioidea), a new, morphologically cryptic bush-cricket species from the Eastern Carpathians (Romania) recognized from its peculiar male calling song. *Zootaxa*, 2627, 57–68.

Orci, K.M., Nagy, B., Szövényi, G., Rácz, I. & Varga, Z. (2005) A comparative study on the song and morphology of *Isophya stysi* Čejchan, 1958 and *Isophya modestior* Brunner von Wattenwyl, 1882 (Orthoptera, Tettigoniidae). *Zoologischer Anzeiger*, 244(1), 31–42.

Ragge, D.R, & Reynolds, W.J. (1998) *The songs of the grasshoppers and crickets of western Europe.* Colchester, Harley Books, 591 pp.

Sueur, J. (2006) Insect species and their songs. *In*: Drosopoulos S, & Claridge M, (Eds), *Insect Sounds and Communication: Physiology, Behaviour, Ecology, and Evolution.* Boca Raton, FL: Taylor & Francis, pp. 207–217.

Sueur, J. & Puissant, S. (2007) Similar look but different song: a new *Cicadetta* species in the *montana* complex (Insecta, Hemiptera, Cicadidae). *Zootaxa*, 1442, 55–68.

Sevgili, H., Ciplak, B., Heller, K.-G. & Demirsoy, A. (2006) Morphology, bioacoustics and phylogeography of the *Isophya major* group (Orthoptera: Tettigoniidae: Phaneropterinae): A species complex occurring in Anatolia and Cyprus. *European Journal of Entomology*, 103, 65–671.

Sevgili, H., Ciplak, Demirsoy, A. & Çiplak, B. (2012) Description and bioacoustics of a new species of the genus Isophya (Orthoptera: Tetigoniidae: Phaneropterinae) from Turkey. *Zootaxa*, 3361, 33–44.

Sevgili, H. & Heller, K.-G. (2003) A new species of the genus *Isophya* Brunner von Wattenwyl from Turkey. *Tijdschrift voor Entomologie*, 146, 39–44.

Szövényi, G. & Orci, K.M. (2008) Contributions to the Orthoptera fauna of Maramureş county with the first record of *Isophya posthumoidalis* Bazyluk 1971 in Romania. *Studia Universitatis Vasile Goldis, Seria Stiintele Vieti* 19, 235–241.

Ünal, M. (2010) Phaneropterinae (Orthoptera: Tettigoniidae) from Turkey and the Middle East II. *Transactions of the American Entomological Society*, 136, 125–183.

Walker, T.J., Forrest, T.G. & Spooner, J.D. (2003) The *rotundifolia* complex of the genus *Amblycorypha* (Orthoptera: Tettigoniidae): Songs reveal new species. *Annals of the Entomological Society of America*, 96, 433–447.

Warchalowska-Sliva, E., Chobanov, D.P., Grzywacz, B. & Maryanska-Nadachowska, A. (2008) Taxonomy of the genus *Isophya* (Orthoptera, Phaneropteridae, Barbitistinae): comparison of karyological and morphological data. *Folia Biologica (Kraków)*, 56, 227–241.

Zhantiev, R.D. & Dubrovin, N.N. (1977) Sound communication in the genus *Isophya* (Orthoptera, Tettigoniidae). *Zoologicheskie Zhurnal*, 56, 38–51.

Zuna-Kratky, T., Karner-Ranner E., Lederer, E., Braun, B., Berg, H-M., Denner, M., Bieringer, G., Ranner, A. & Zechner, L. (2009) Verbreitungsatlas der Heuschrecken und Fangschrecken Ostösterreichs. Naturhistorisches Museum Wien, Wien, 303 pp.