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Two new cryptic *Leptophyes* species from southern Italy (Orthoptera: Tettigoniidae)

ROY M.J.C. KLEUKERS[1], BAUDEWIJN ODÉ[2] & PAOLO FONTANA[3]

[1]*European Invertebrate Survey - The Netherlands / Netherlands Centre for Biodiversity Naturalis, Postbus 9517, 2300 RA Leiden, The Netherlands. E-mail: kleukers@naturalis.nl*

[2]*P.C. Hooftstraat 149, 1071 BT Amsterdam, The Netherlands. E-mail: baudewijn.ode@hetnet.nl*

[3]*Fondazione Edmund Mach - Ist. Agrario S. Michele all'Adige, Centro Trasferimento Tecnologico - Fitoiatria, Via Edmund Mach 1, 38010 San Michele all'Adige (TN) Italy. E-mail: paolo.fontana1@iasma.it*

Abstract

In this paper two new species of *Leptophyes* from southern Italy are described, *L. calabra* **n. sp.** and *L. sicula* **n. sp..** Both species are similar to the common *L. punctatissima* and the recently described *L. lisae* from Greece, but can be identified by a combination of morphological and biacoustical characters. Descriptions of both species are provided and an illustrated key to the European species of *Leptophyes* is presented. These new findings are remarkable as the genus *Leptophyes* harbours only 15 species worldwide. This study suggests that the *Leptophyes punctatissima* - group in southern Europe is in need of a thorough survey. It is essential that bioacoustical information be involved in this study.

Key words: *Leptophyes calabra*; *Leptophyes sicula*; bioacoustics; song; distribution

Introduction

The genus *Leptophyes* Fieber, 1853 contains 15 species worldwide (Eades & Otte 2009), of which six occur in Europe (Heller 2007, Heller *et al.* 1998). The number of species was quite stable, but recently Heller & Willemse, 1989 described *Leptophyes lisae* from Greece and Naskrecki & Ünal (1995) and Sevgili (2004) described two new species from Turkey.

FIGURE 1. *Leptophyes calabra*, male (holotype) at the type locality Tiriolo, Calabria (2008). Holotype. Photo R. Kleukers.

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In 2008 two male specimens of a *Leptophyes* species were found on Monte Tiriolo in the region Calabria in southern Italy (Fig. 1, 2). The specimens resembled *L. punctatissima*, but the colouration was atypical and later the song proved to be clearly different. This finding triggered the re-evaluation of a recent record of *Leptophyes* in Sicily. In 1998 the third author found some nymphs of a *Leptophyes* species near Siracusa, of which he reared four males and one female to adult (Fig. 3). These resembled *L. punctatissima* morphologically, but the song was different. These species are described here as *L. calabra* **n. sp**. and *L. sicula* **n. sp**., respectively**.**

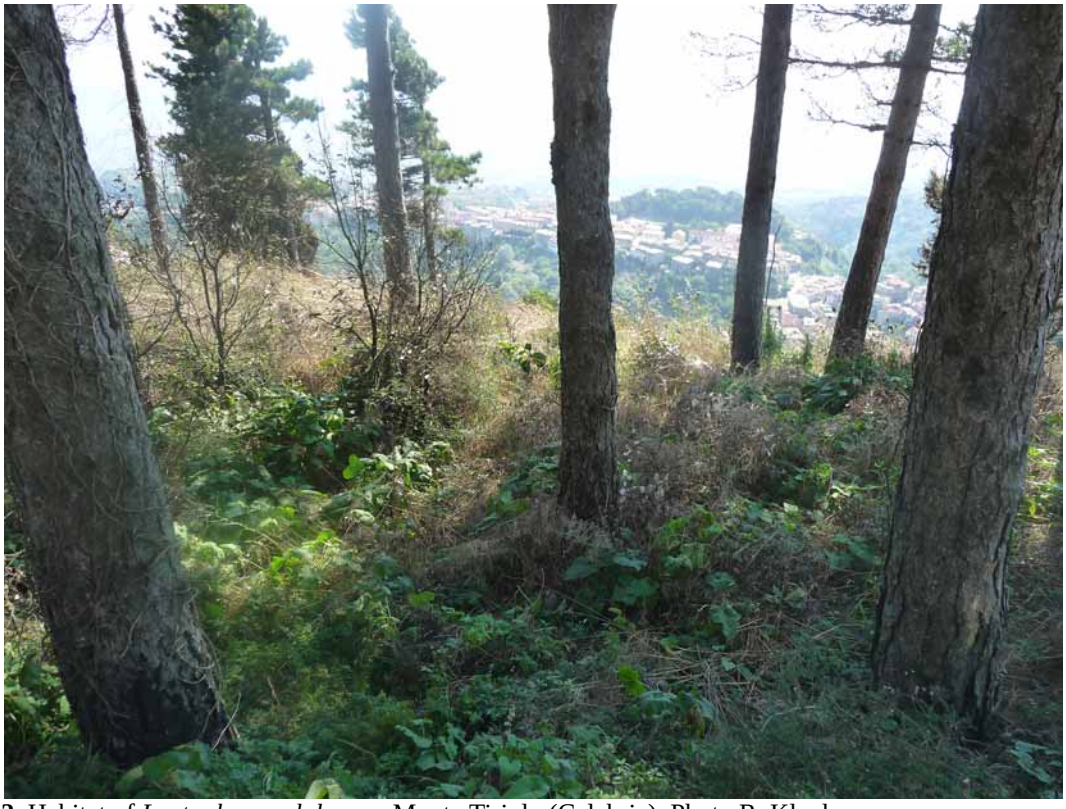

FIGURE 2. Habitat of *Leptophyes calabra* on Monte Tiriolo (Calabria). Photo R. Kleukers.

Materials and methods

Material examined. *Leptophyes* specimens from the following collections were included in this study: F. Willemse (Eygelshoven), P. Fontana (Isola Vicentina), R. Kleukers (Leiden), Dutch Centre for Biodiversity Naturalis (Leiden, RMNH). Material for the newly described species is listed within the descriptions.

Fieldwork. The *Leptophyes* specimens were visually spotted during regular Orthoptera fieldwork. The specimens of *L. sicula* were caught as nymphs and raised to the adult stage in a terrarium.

Bioacoustics. The sound recordings were made indoors from the calling song of isolated singing males. The recordings of *L. sicula* were made with a Philips portable DCC-recorder (Philips DCC 170), using a Sony microphone and yielded in 16 bits, 44.1 kHz digital recordings with a frequency response of about 20–18.000 Hz.

Leptophyes calabra has been recorded with a Tascam HD-P2 portable solid state recorder, with Sennheiser microphones (module K6 with head ME40) and through a batdetector Petersson D240 with time expansion. The first method results in 24 bits 96 kHz recordings with a frequency response of about 20–40.000Hz, although frequencies below 22kHz tend to be overrepresented. As a result of the possible poor frequency response, these recordings have only been used to analyse temporal characters. The second method results in 8 bits 300kHz sampled fragments in the bat detector, played back with a 10 times lowered speed, with a frequency response of 10–120kHz (lowered 1–12kHz). The latter recordings have been used to analyze the overall spectrum of the song, as well as temporal aspects.

Temporal and spectral qualities of the songs have been analyzed with Bias Peak software and transformed to oscillograms using Praat linguistical software.

Terminology. Syllable = the sound produced with a complete opening and closing movement of the wings; fragment = parts of the syllable that are separated by clear silent intervals; pulse = sound pulse as visible in oscillograms, sometimes coinciding with single tooth-strokes on the stridulatory file.

Photography. The photo's of the morphological details were made with a Leica digital camera DFC420 connected to a Leica stereomicroscope MZ16A, in most cases using stacking technique.

FIGURE 3. Male *Leptophyes sicula*, reared from nymph. Cava Grande del Cassabile, Sicily (1998). Photo Paolo Fontana.

Descriptions

***Leptophyes calabra* nov. spec.**

Figs 1, 2, 4a–g, 5a–h, 9g, 10g, 13c, 14c, 15c, 16g, 17d

Material: Holotype: male, 7-VIII-2008, top of Monte Tiriolo, 3 km E Tiriolo, N38º57'01.3"E16º30'57.2", 830 m above sealevel, col. RMNH Leiden. Paratype: 1 male, same data, col. RMNH Leiden.

Recordings: Baudewijn Odé, ita08-h: take 00, 01, 02, 08; ita08-s: take 00 (all from holotype).

Diagnosis: The male can be distinguished easily from *L. albovittata, L. boscii, L. discoidalis* and *L. laticauda*, by the shape of the cercus and, in the first three species, the length of the elytra. Of the other three European *Leptophyes* species it is morphologically most similar to *L. punctatissima*, although the cercus is not constricted in *L. punctatissima* and the dorsal stripe on the abdomen is reddish brown instead of crème coloured. The best feature is the song, the syllable broken up into three fragments in *L. calabra* and unfragmented in *L. punctatissima*.

Morphologically *L. calabra* is quite different from both *L. lisae and L. sicula*, by the shape of the cercus, the bulge at the hind edge of the elytron and the form of the stridulatory file. The song is distinct from *L. sicula*, but similar to that of *L. lisae*, the syllable being broken up in three fragments. The last fragment is quite long in *L. lisae* but very short in *L. calabra*. A summary is given in table 1 and Fig. 13–16. The female is as yet unknown.

Male: Head with fastigium narrow. Pronotum quite flat, only slightly upturned at the hind margin (Fig. 4a). Elytron more or less round, with a slight bulging at the hind margin (Fig. 4d), visible part of the elytron

approximately the length of the pronotum (Fig. 4a). Stridulatory file with 56 (holotype) and 94 (paratype) teeth. The teeth widen sharply in the basal part of the file, for the remaining 90% more or less equally broad (Fig. 4f). Cercus slender and evenly curved, tapering into a sharp, dark point, somewhat constricted at 2/3 of its length (Fig. 4c). Subgenital plate long and narrow, extending beyond the tip of the cerci.

General colour in living animals light green, with numerous dark spots (Fig. 1). Pronotum dorsally whitish with red margins. Elytron mostly crème coloured, with dark brown markings, fore margin green. Fore tibia and antennal base red. Abdomen dorsally with creme coloured stripe. Because only two specimens are known, the variability of the colour has to be investigated further.

Measurements (in mm, n = 2): body 13.6 mm, pronotum 2.4 mm, visible part elytron 2.5–3.2 mm, hind femur 14.4 mm.

Female: unknown

Sound: The following description is based upon several recordings of one specimen. The song consists of a repetition of short clicking sounds of about 170 ms, repeated every 1–4s, each consisting of three fragments (Fig. 5). The first two fragments consists of a series of 10–14 pulses. Rarely the first fragment is absent. The third fragment consists of 1(-2) loud pulses, sometimes followed by another pulse at short distance. The frequency spectrum of the first two fragments shows a broad peak around 30 kHz. The third loud fragment in a syllable shows a slightly higher peak, around 35 kHz.

There is no wing movement analysis available. Yet, we assume that the movement is comparable to that of *L.lisae*, which has a similar song (Heller & Willemse 1989). This suggests that the three fragments of a song all are produced during a single closing movement of wings and the song consists of a single syllable. The silent intervals between fragments are produced during a pause in this movement. Wing movement analysis might reveal which part of the stridulatory file is involved in the production of the different fragments.

Distribution: Up to now the species is only known from the type locality Monte Tiriolo in the region Calabria (Italy) (Fig. 17d). The known records of *L. punctatissima* in southern Italy (Fontana *et al.* 2006) might all or partly refer to *L. calabra*, but this has to be investigated further.

Habitat: The two specimens have been found at 800 m above sea level near the top of Monte Tiriolo, in the undergrowth of herbs and grasses in a light mixed forest of pine trees and some deciduous trees and bushes (Fig. 2).

Etymology: A noun in apposition. The species is named after the region Calabria where the only known locality is situated.

TABLE 1. Differences between the males of *L. punctatissima*, *L. lisae, L. calabra* and *L. sicula*. See figures 13–15.

	L. punctatissima	*L. lisae*	*L. calabra*	*L. sicula*
Cercus	Not constricted, bent at ca. 2/3 length	Contricted and bent at ca. 1/2 length	Constricted and bent at ca. 2/3 length	Contricted and bent at ca. 1/2 length
Stridulatory teeth	60–70 (90)	90–120	50–100	110–125
Stridulatory file	distal 90 % eq. broad	distal 70 % eq. broad	distal 90 % eq. broad	middle 50% eq. broad
Bulge elytron	weak	strong	weak	strong
Song	unfragmented syllable of 20 ms	syllable broken into three fragments	syllable broken into three fragments, the last one very short	unfragmented syllable of 40–50 ms

***Leptophyes sicula* nov. spec.**

Figs 3, 6a–g, 7a–j, 8a–c, 9h, 10h, 12g, 13d, 14d, 15d, 16h, 17d.

Material: Holotype: male, 30-V-1998, Italy: Sicily, Cava Grande del Cassabile, reared from nymph, P. Fontana, col. RMNH Leiden. Paratypes: 4 males and 1 female, same data, col. Fontana.
Recordings: Paolo Fontana, PF1998-2A: 11-13 (BF, holotype); PF1998-2B: 4 (AF, paratype) .

Diagnosis: The male can be distinguished easily from *L. albovittata, L. boscii, L. discoidalis* and *L. laticauda*, by the shape of the cercus and, in the first three species, the length of the elytra. Of the remaining

European *Leptophyes* species it is morphologically similar to *L. lisae* of Greece. The song, however is different, the syllable being unfragmented, while the syllable of *L. lisae* is broken into three fragments. It can be recognized from both *L. punctatissima* and *L. calabra* by the shape of the cercus, bulge at the hind edge of the elytron, form of the stridulatory file and the number of stridulatory teeth. The song is useful for the distinction with *L. calabra* (similar to the song of *L. lisae*), but the song of *L. punctatissima* is similar tot that of *L. sicula*. A summary is given in table 1 and figure 13–16.

The female is different from *L. boscii* and *L. discoidalis* in the absence of the notch at the base of the ovipositor. The ovipositor is clearly longer than in *L. albovittata* and shorter than in *L. laticauda*. We found no clear distinguishing characters with *L. punctatissima* and *L. lisae* (the female of *L. calabra* is unknown). Heller & Willemse (1989) mention the size of the lateral pit of the ovipositor, body colour and the shape of the hind margin of the pronotum to separate *L. lisae* from *L. punctatissima*, but they also conclude that the distinction is often difficult.

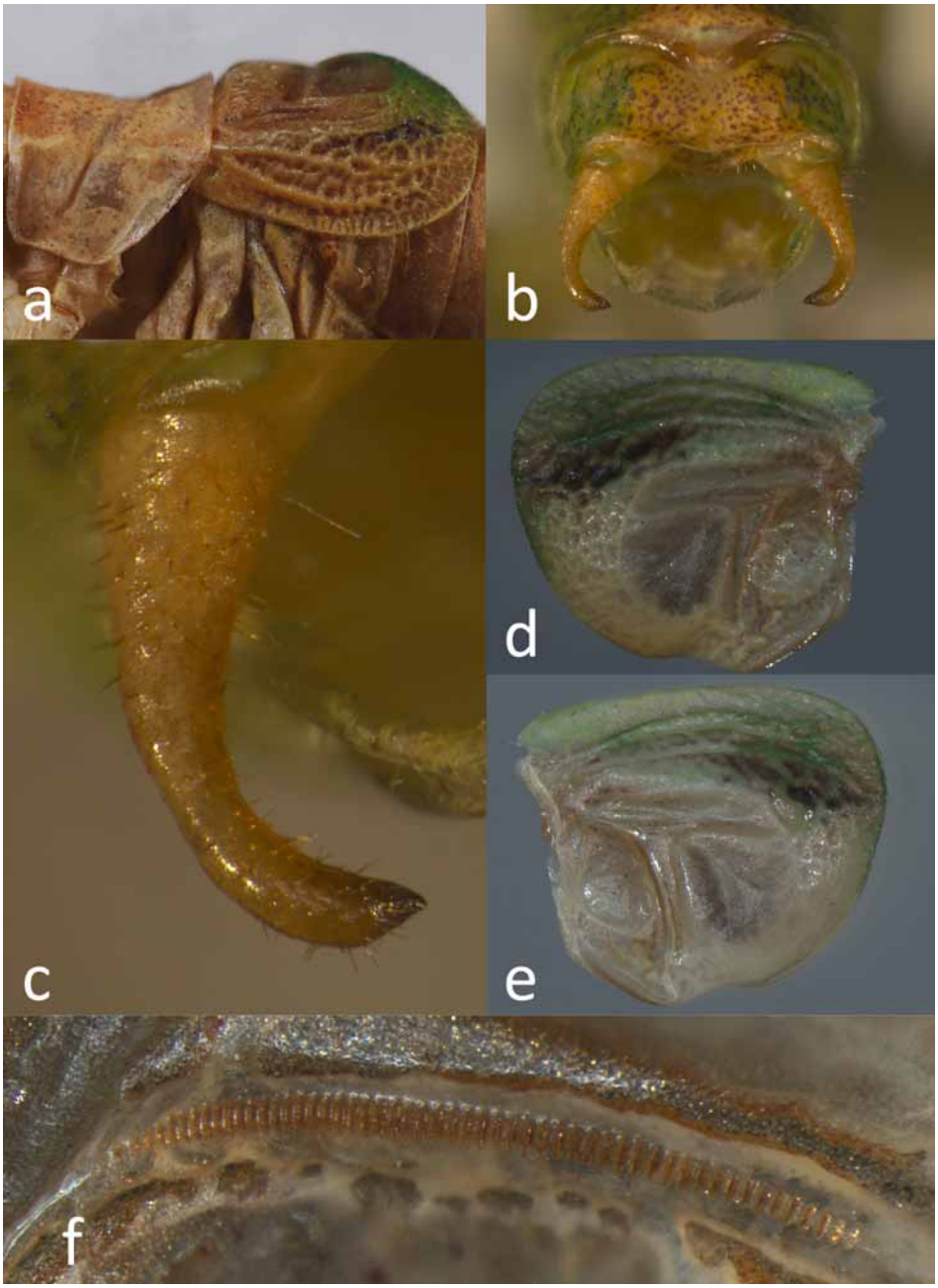

FIGURE 4. *Leptophyes calabra* male, a. pronotum and elytron (lateral view), b. supra-anal plate and cerci, c. cercus, d. elytron (dorsal), e. elytron (ventral), f. stridulatory file. All detailphoto's by R. Kleukers & P. Fontana.

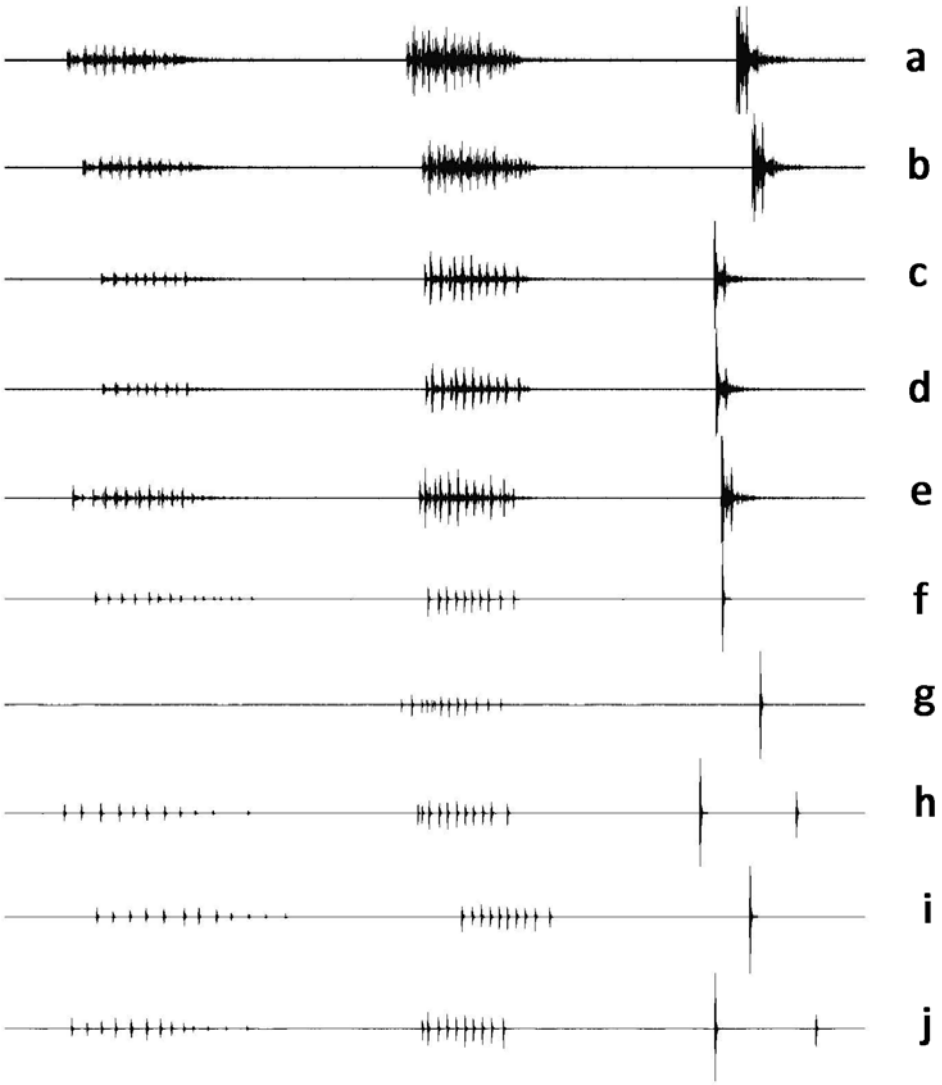

FIGURE 5. Oscillograms (200 ms) of calling song of *Leptophyes calabra*. a–e: Specimen 2: Rec. Baudewijn Odé, 22.VIII.2008 from time stretched recording via batdetector, 19˚C, recording ita08-s: take 00; f–j: Specimen 2: Rec. Baudewijn Odé, 22.VIII.2008 at 24bits/96kHz, 19˚C, recording ita08-h: take 08.

Description. Male: Head with fastigium narrow. Pronotum quite flat, slightly upturned at the hind margin (Fig. 6a). Elytron more or less round, with a strong bulging at the hind margin (Fig. 6e), visible part of the elytron approximately the length of the pronotum (Fig. 6a). Stridulatory file with 110–124 teeth. In the basal part of the file the teeth are narrow and irregularly spaced, in the distal 2/3 part the teeth are broad and regularly spaced (Fig. 6g). Cercus slender and evenly curved, tapering into a sharp, dark point. The cercus somewhat constricted at 1/2 of its length (Fig. 6c). Subgenital plate long and narrow, extending beyond the tip of the cerci.

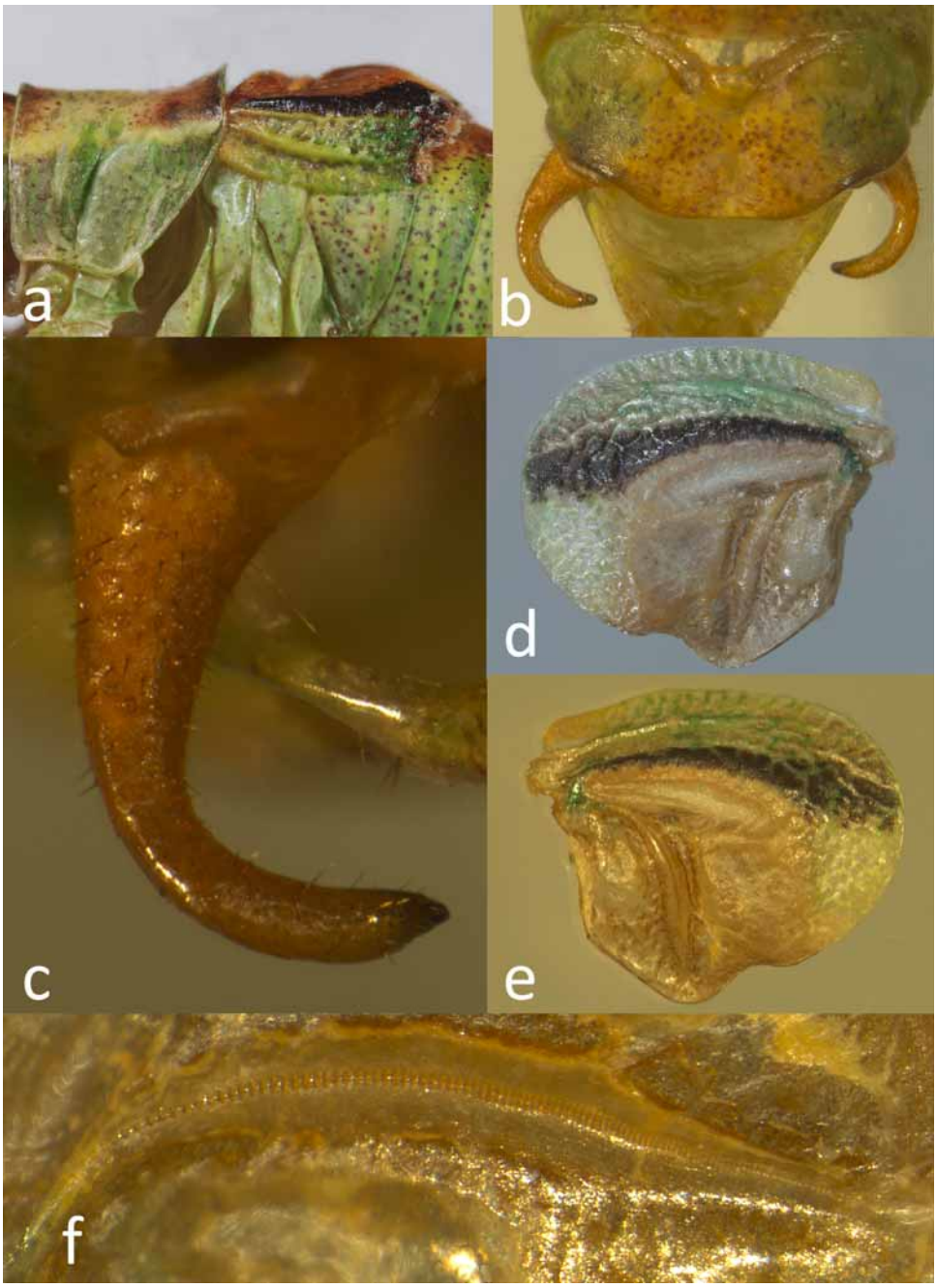

FIGURE 6. *Leptophyes sicula* male, a. pronotum and elytron (lateral view), b. supra-anal plate and cerci, c. cercus, d. elytron (dorsal), e. elytron (ventral), f. stridulatory file. All detailphoto's by R. Kleukers.

General colour in living animals light green, with numerous reddish-brown spots (Fig. 3). Pronotum dorsally greenish with creme coloured margins. Elytron dorsally mostly brownish, with black stripe and green foremargin. In some specimens the region around the stridulatory file lighter than the surrounding area. Abdomen dorsally with red brown stripe.

Measurements (n = 5): body 13.7–15.2 mm, pronotum 2.4 mm, visible part elytron 2.7–3.2 mm, hind femur 13.6–15.1 mm.

Female: Head with fastigium narrow. Pronotum quite flat, not upturned at the hind margin (Fig. 8a). Visible part of the elytron approximately half of the length of the pronotum (Fig. 8b). Ovipositor evenly curved (Fig. 8c). General colour in living animals light green, with numerous reddish-brown spots (Fig. 8c). Pronotum dorsally greenish with crème coloured margins. Elytron dorsally mostly yellow-brown, with black stripe and green foremargin. Abdomen dorsally with red brown stripe.

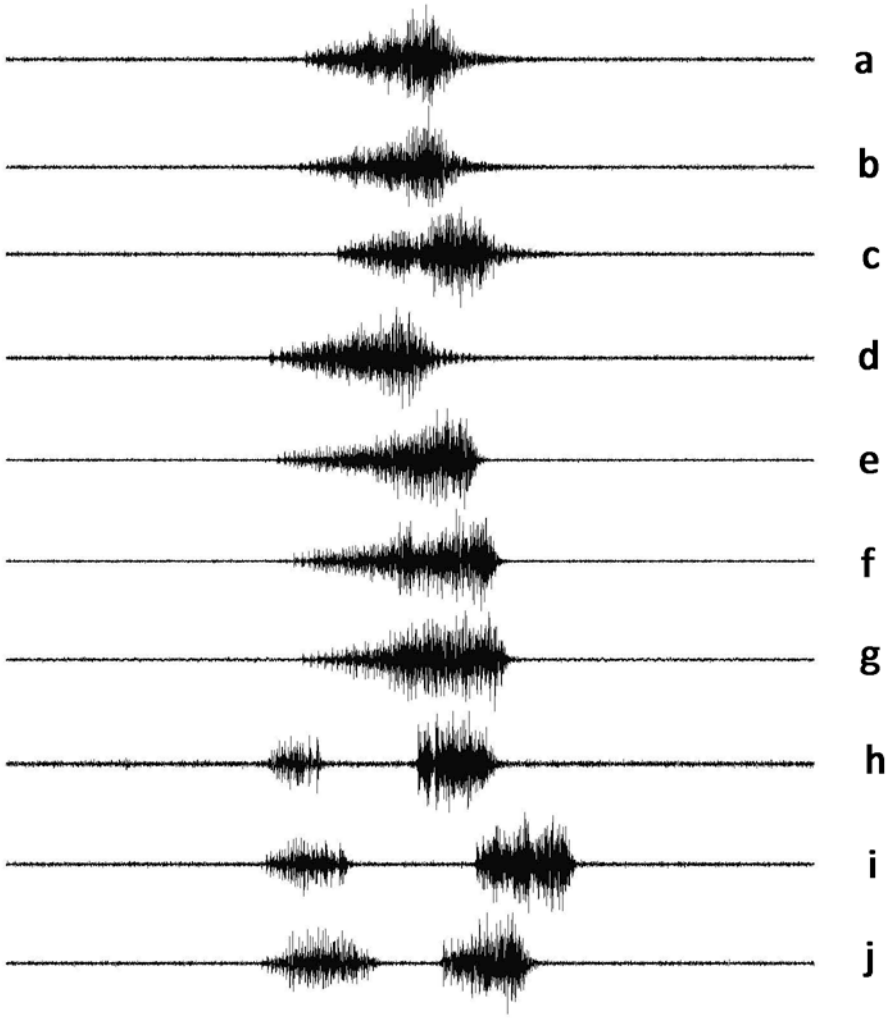

FIGURE 7. Oscillograms (200 ms) of calling song of *Leptophyes sicula*. a–d: Specimen AF: Rec. Paolo Fontana, 5.VII.1998 at 16bits/44.1kHz, 27˚C, tape PF1998-2B: 4; e–j: Specimen BF: Rec. Paolo Fontana, 3.VII.1998 at 16bits/44.1kHz, 27˚C, tape PF1998-2A: 13.

Measurements (n = 1): body (without ovipositor) 17.6 mm, pronotum 3.2 mm, visible part elytron 1.9 mm, hind femur 16.8 mm, ovipositor 7.2 mm.

Sound: The song is a more or less regular repetition of a ticking sound, exceptionally broken in two fragments in close distance (Fig. 7). Analogous to other species of the genus it has to be regarded as a simple syllable, lasting about 40–50 ms. These syllables are repeated every 0,5–3 s. Although the resolution of the available recordings is not sufficient, it is clear that the syllable consists at least of about 8–15 pulses. A reliable frequency spectrum could not be established, as the available recordings do not include frequencies above 20 kHz.

Distribution: The species is only known from the type locality Cava Grande del Cassabile in the southeast of Sicily, south of the town of Siracusa in the Monti Iblei (Fig. 17d). Possibly all records of *L. punctatissima* of Sicily (summarized in Fontana *et al.* (2006)) refer to *L. sicula*, but this has to be investigated further.

Habitat: Many nymphs were observed on small shrubs and large herbs in dense Mediterranean macchia in the upper part of the deepest and largest gorge in Sicily (cava meaning gorge in Sicily).

Etymology: A noun in apposition. The species is named after the island Sicily where the only known locality is situated.

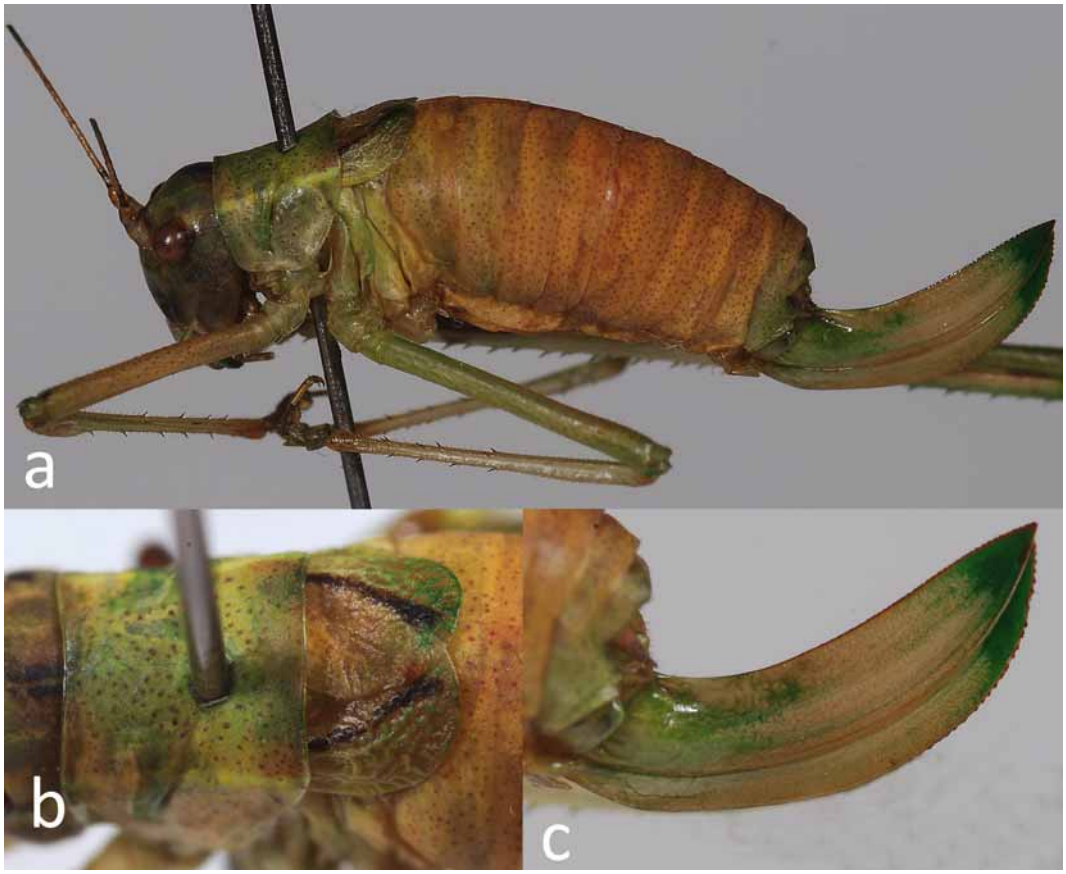

FIGURE 8. *Leptophyes sicula* female, a. habitus (lateral view), b. pronotum and elytron (dorsal), c. ovipositor.

The genus *Leptophyes* in Europe

In Europe eight species of *Leptophyes* are now known to occur:

L. albovittata (Kollar, 1833)
L. boscii Fieber, 1853
L. calabra **spec. nov.**
L. discoidalis (Frivaldszky, 1867)
L. laticauda (Frivaldszky, 1867)
L. lisae Heller & Willemse, 1989
L. punctatissima (Bosc, 1792)
L. sicula **spec. nov.**

Males of most species can be easily identified by morphological characters (see Identification key), but especially for the males of the *L. punctatissima* - group the song is the easiest character (see Bioacoustics). The females are more difficult to identify. The character to separate *L. boscii* from *L. discoidalis*, placement of the node under or at the base of the gonangulum at the side of the ovipositor, as mentioned by Harz (1969) doesn't seem to be valid. No reliable character is available at the moment. Also the females of the *L. punctatissima* - group are difficult to identify. It is advised to collect males, wherever possible.

In table 1 and figure 13-16 the characters for the males *Leptophyes punctatissima* - group are summarized. In figure 17 the distribution of the species in Europe is depicted. The records of *L. discoidalis* for Italy (Romagna: Campigna and Toscana: Mt. Grabendo) of Schmidt (1989, p. 16) have been omitted. The third author examined the voucher specimens in the collection of the Zoologische Staatssammlung München and they proved to belong to *L. boscii*.

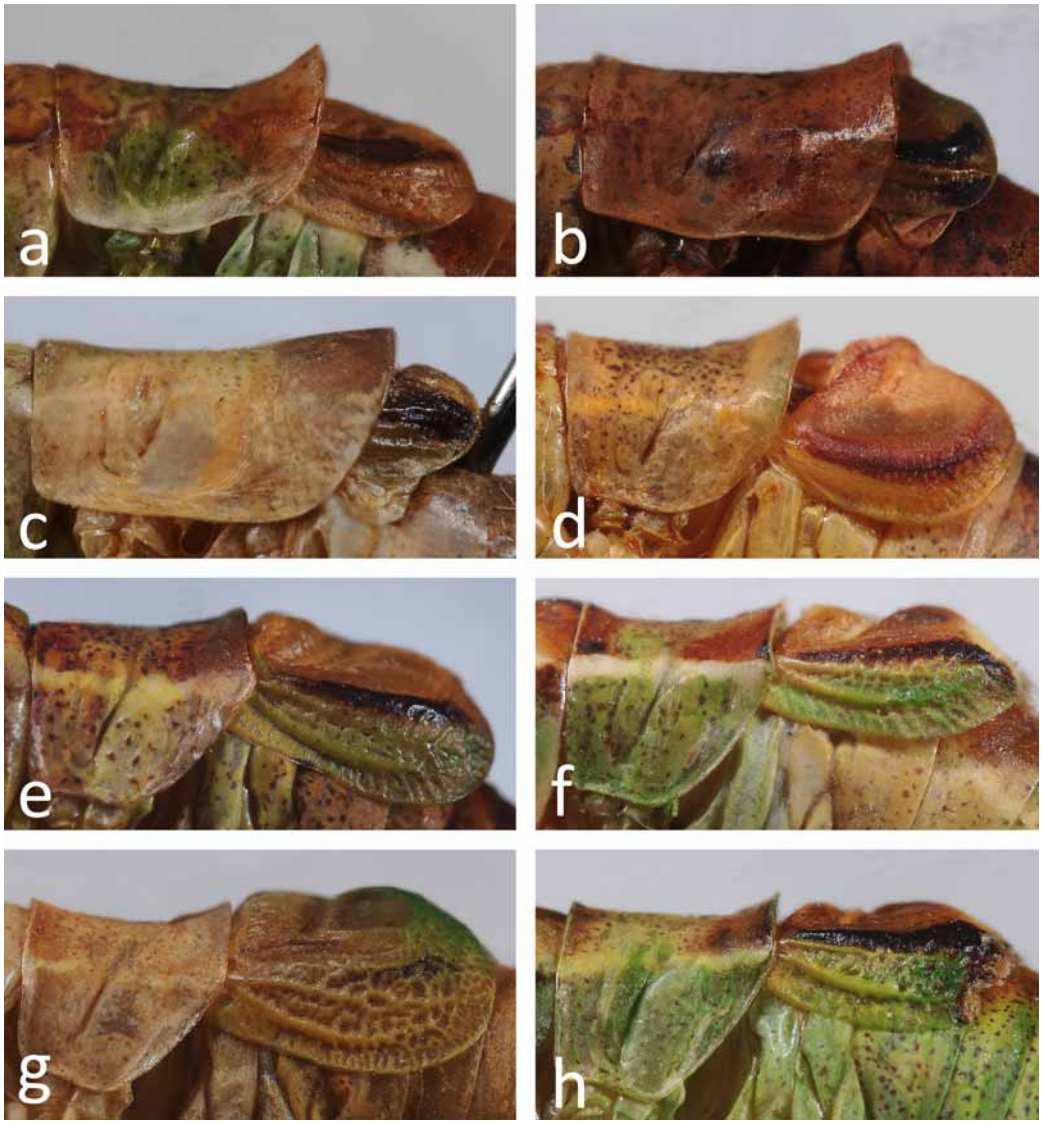

FIGURE 9. Pronotum and elytron of the males of the European *Leptophyes* species (dorsal view), a. *L. albovittata*, b. *L. boscii*, c. *L. discoidalis*, d. *L. laticauda*, e. *L. punctatissima*, f. *L. lisae*, g. *L. calabra*, h. *L. sicula*.

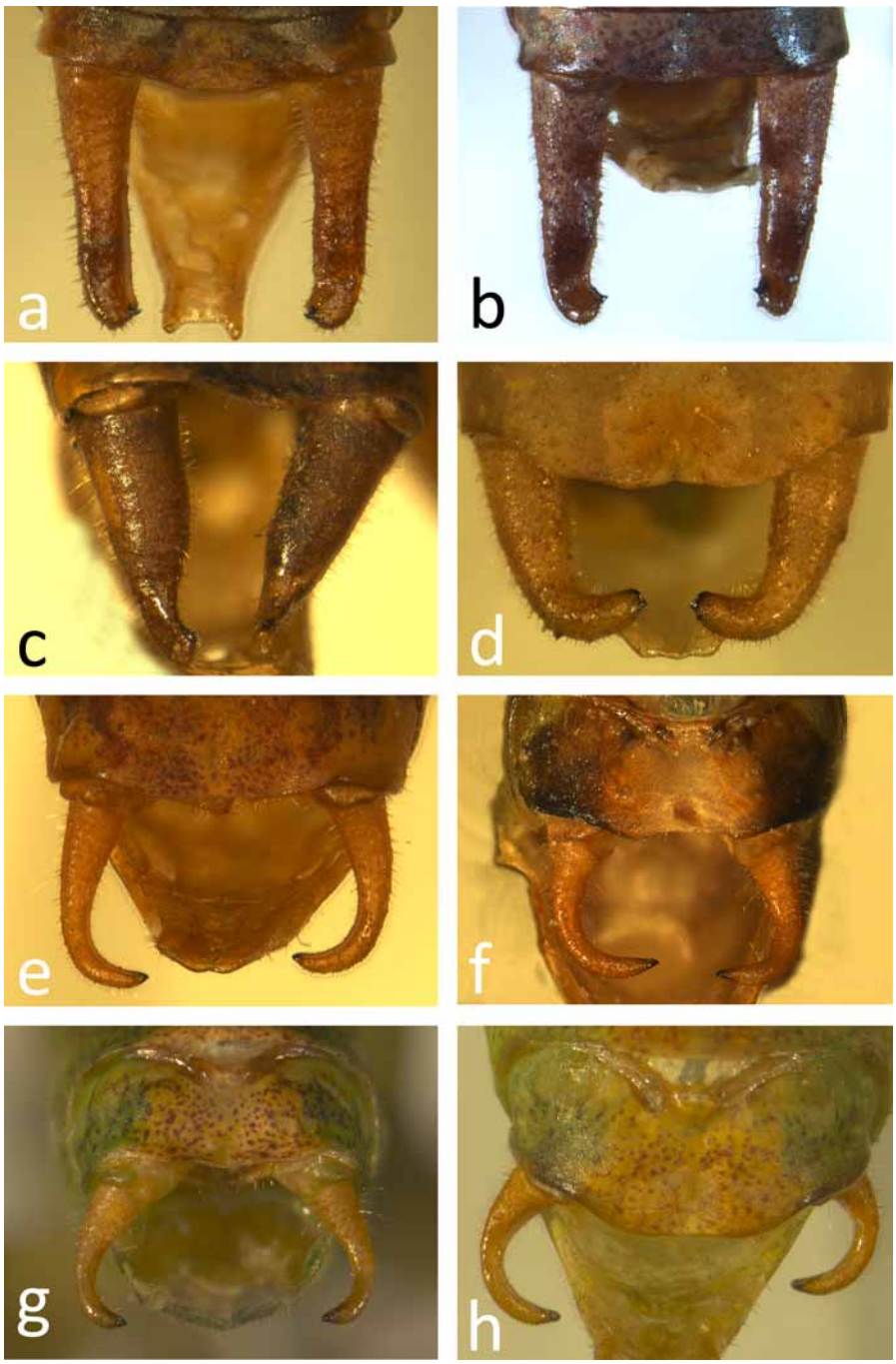

FIGURE 10. Supra-anal plate and cerci of the males of the European *Leptophyes* species (dorsal view), a. *L. albovittata*, b. *L. boscii*, c. *L. discoidalis*, d. *L. laticauda*, e. *L. punctatissima*, f. *L. lisae*, g. *L. calabra*, h. *L. sicula*.

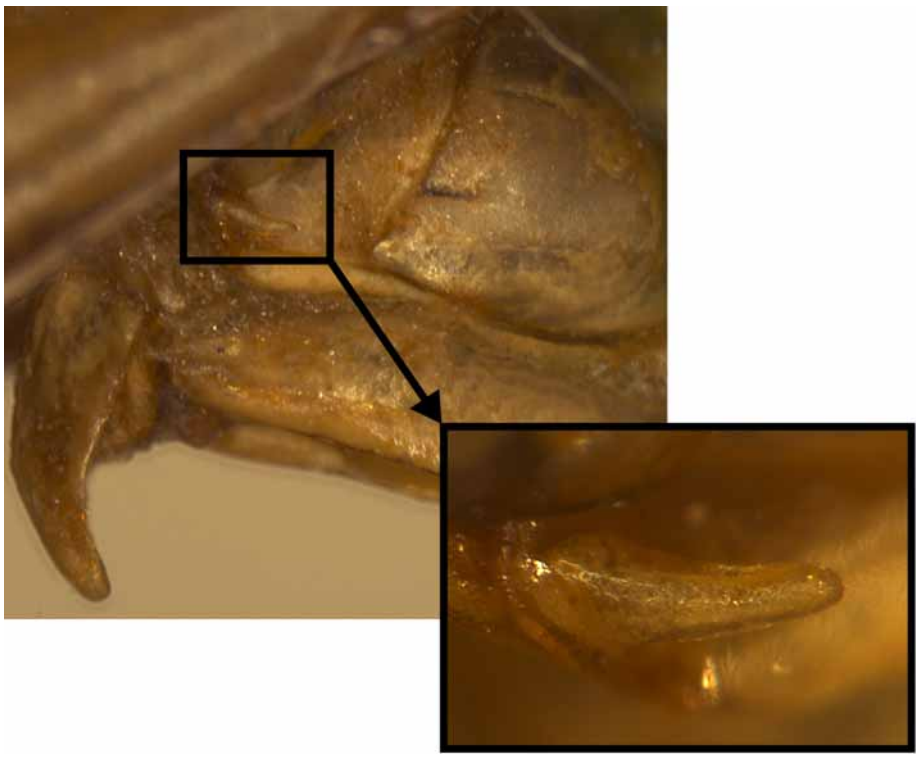

FIGURE 11. Notch at base ovipositor *L. discoidalis* (lateral view). This character is also present in *L. boscii.*

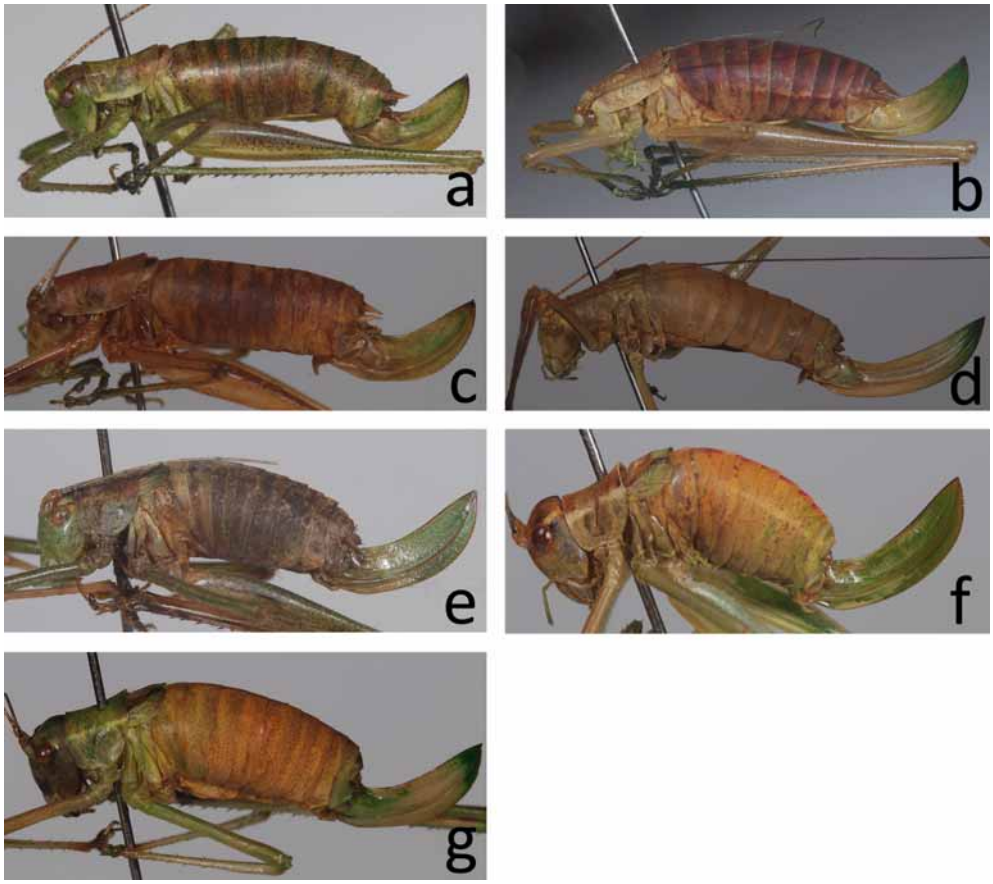

FIGURE 12. Habitus of the females of the European *Leptophyes* species (lateral view), a. *L. albovittata*, b. *L. boscii*, c. *L. discoidalis*, d. *L. laticauda*, e. *L. punctatissima*, f. *L. lisae*, g. *L. sicula*. The female of *L. calabra* is unknown.

Identification key

1 Ovipositor absent, males 2
- Ovipositor present, females (female of *L. calabra* unknown) 9

Males

2 Pronotum 2 x as long as high, visible part of elytron extending at maximum 0.5 x the length of the pronotum (Fig. 9a-c), cercus more or less straight (Fig. 10a–c) 3
- Pronotum as long as high, visible part elytron extending at least 1 x the length of the pronotum (Fig. 9d–h), cercus bent (Fig. 9d–h) 5
3 Cercus very broad at base, at 3/4 suddenly narrowed (Fig. 10c) ..... *L. discoidalis*
- Cercus slender along its entire length (Fig. 10a–b) 4
4 Pronotum curved gently upward apically, visible part elytron < 0,25 x the length of pronotum (Fig. 9b), cercus with tip flattened and turned upward (Fig. 10b) ..... *L. boscii*
- Pronotum curved strongly upward apically, visible part elytron 0.5 x the length of pronotum (Fig. 9a), cercus with tip rounded and not turned upward (Fig. 10a) ..... *L. albovittata*
5 Cercus stout and angularly bent, with a blunt tip and broad black tip (Fig. 10d) ..... *L. laticauda*
- Cercus slender and evenly bent, with pointy black tip (Fig. 10e–h) 6
6 Elytron with weak bulge at hind margin elytron (Fig. 13a, c), cercus bent at 1/5 of the apex (Fig. 14a, c) 7
- Wing with strong bulge at hind margin elytron (Fig. 13b, d), cercus bent at 1/3 of the apex (Fig. 14b, d) 8
7 Cercus gradually tapering towards the apex, without widened apex (Fig. 14a) ..... *L. punctatissima*
- Cercus constricted at 1/2–2/3 of its length (Fig. 14b–d) ..... *L. calabra*
8 Song consists of repeated clicking sounds, each consisting of 3 fragments (Fig. 16f) ..... *L. lisae*
- Song consists of repeated single (rarely double) ticking sounds (Fig. 16h) ..... *L. sicula*

Females (female of *L. calabra* unknown)

9. Visible part elytron < 0.3 x length pronotum (Fig. 12a–c) 10
- Visible part elytron 0.5 x length pronotum (Fig. 12d–g) 11
10 Ovipositor circa length pronotum (Fig. 12a); no notch at base of ovipositor ..... *L. abovittata*
- Ovipositor clearly larger that length pronotum (Fig. 12b–c); notch at base of ovipositor (Fig. 11) ..... *L. boscii* / *L. discoidalis*
11 Ovipositor 3 x length pronotum (Fig. 12d) ..... *L. laticauda*
- Ovipositor 2 x length pronotum (Fig. 12e–g) ..... *L. punctatissima/lisae/sicula*

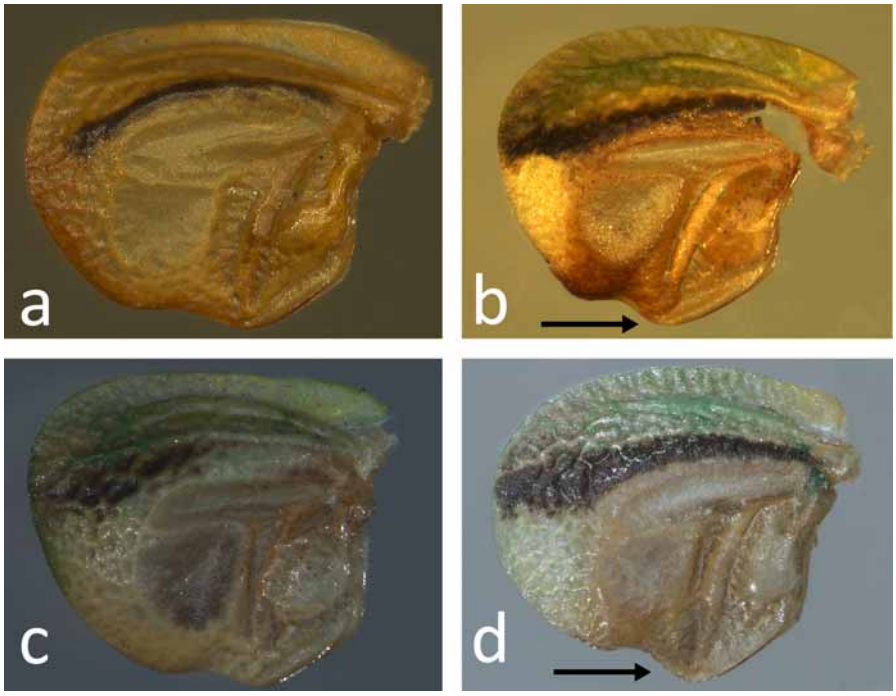

FIGURE 13. Elytron (dorsal view), males, a. *L. punctatissima*, b. *L. lisae*, c. *L. calabra*, d. *L. sicula*.

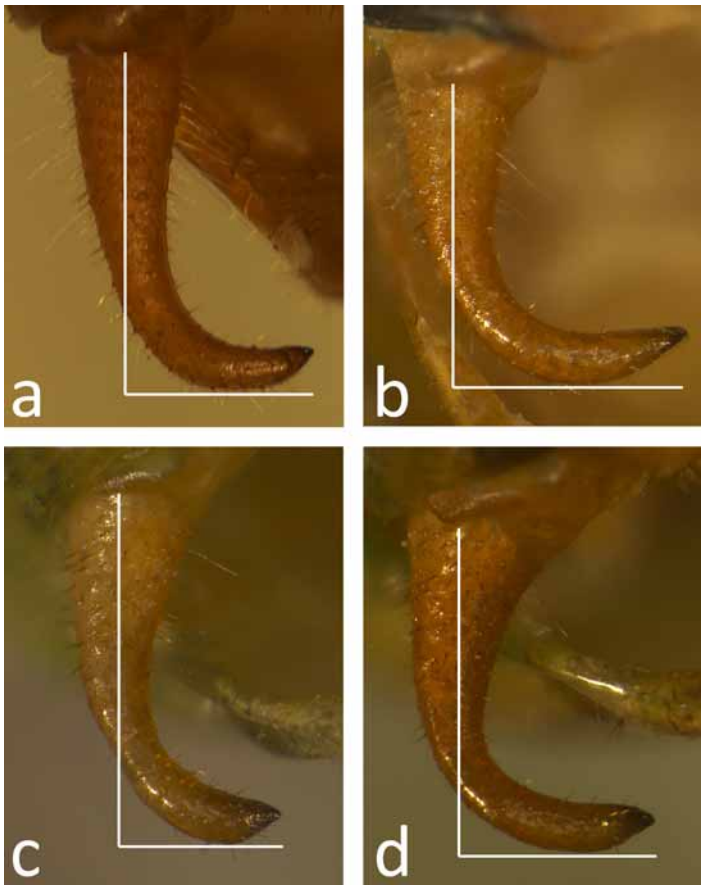

FIGURE 14. Cercus (dorsal view), males, a. *L. punctatissima*, b. *L. lisae*, c. *L. calabra*, d. *L. sicula.*

Bioacoustics

From a bioacoustic perspective the European species of *Leptophyes* are quite similar. Usually the song consists of a short monosyllabic ticking or clicking sound, lasting about 10–150 ms and repeated every 0,5–4s (Fig. 16). The songs have a prominent ultrasonic frequency component. Only *L. discoidalis* has a much different song, with syllables repeated at a rate up to about 20/s and lasting 20–200ms, without being split into fragments (Ingrisch & Pavićević, in press). Most of the other species can be distinguished by the song characters, however not easily. The song of *L. calabra* shows a marked similarity with *L. lisae*, both showing three fragments within the clicking syllable. A prominent difference lies within the duration of the last fragment, being very short in *L. calabra*. The song of *L. sicula* resembles that of *L. punctatissima*, *L. boscii* and *L. albovittata*. Based upon our preliminary analyses syllables in *L. sicula* last relatively long, about 40–50 ms. In the number of pulses (about 8–15) it resembles mostly *L. albovittata*.

Discussion

Riggio (1888a) mentions *Leptophyes punctatissima* for the first time from Sicily. He has one specimen only and finds some differences with typical *L. punctatissima*, but concludes that this is part of the variation of the species. Probably the specimen, which is depicted in Riggio (1888b), belongs to *L. sicula*, although at this moment it can not be excluded that *L. punctatissima* or other as yet undescribed species of *Leptophyes* occur in Sicily. Only a comprehensive study, explicitly including bioacoustics, can shed light on these questions.

The discovery of two new species of *Leptophyes* is surprising. The European Orthoptera are quite well investigated, especially the bioacoustics of the bushcrickets (Heller 1988, Ragge & Reynolds 1998). It seems worthwhile to make a thorough study of the *Leptophyes punctatissima* - complex in the Balkans, Italy and

Spain, involving morphology, bioacoustics and preferably also DNA. This study confirms that bioacoustic information, preferably high resolution sound recordings, is essential for species recognition (Heller 1988, Ragge & Reynolds 1998).

The phylogenetic relationships between the species of the *L. punctatissima* group are unclear. The song seems to indicate an affinity between on the one hand *L. lisae* - *L. calabra* and on the other hand *L. punctatissima* - *L. sicula*. However the form of the stridulatory file, number of teeth on the stridulatory file, form of the elytron and form of the cercus are similar in *L. punctatissima* - *L. calabra* and *L. lisae* - *L. sicula* (table 1). DNA studies could clarify the relationships.

As the female of *L. calabra* is as yet unknown, it will be of interest to collect and describe females from the type locality. Furthermore it will be a challenge to establish the distribution boundaries, variability and potential threats of both species. If the range of the new species is indeed restricted they should be included in a red list of European Orthoptera and conservation measures should be taken as to prevent their extinction.

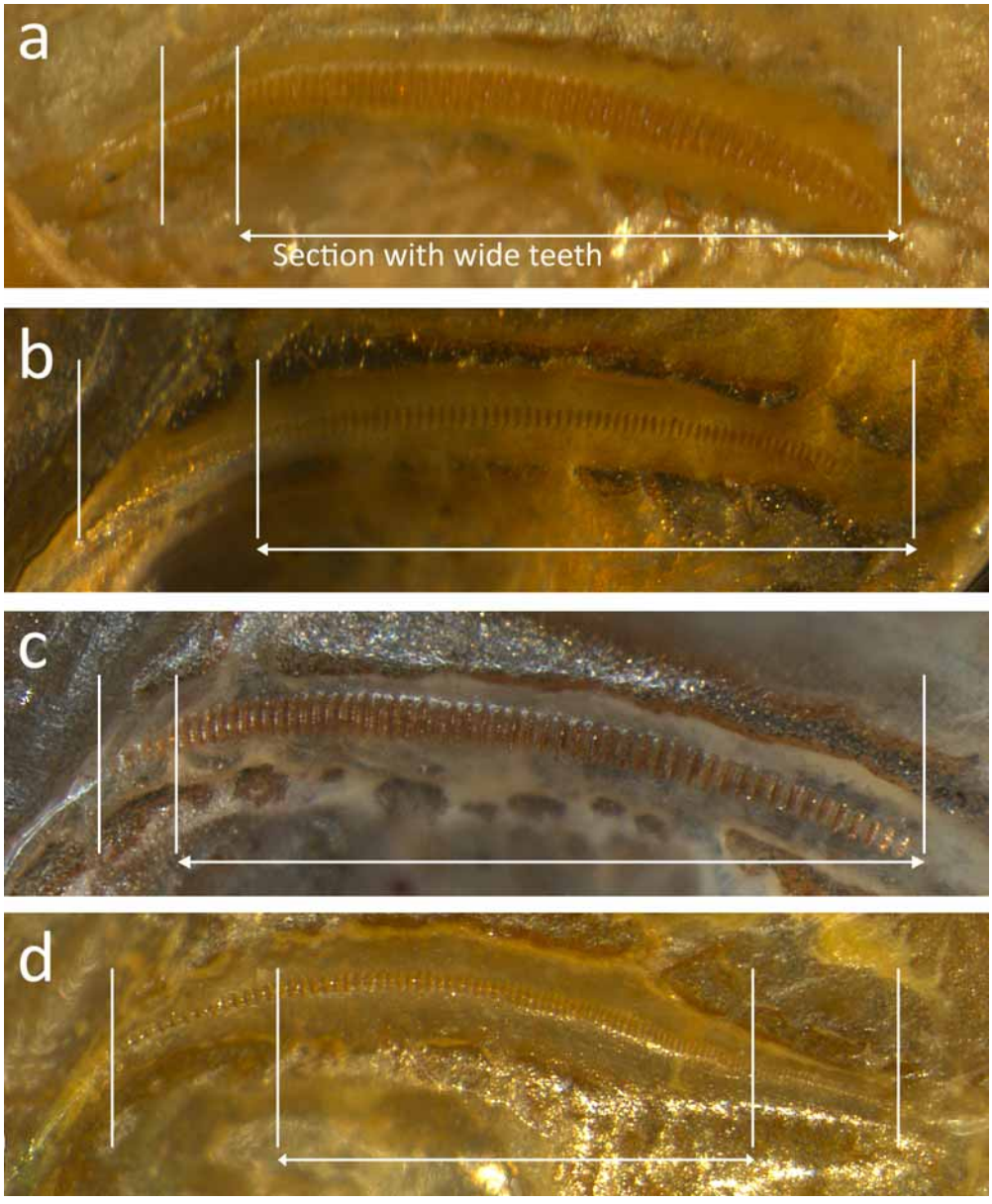

FIGURE 15. Stridulatory file, males, a. *L. punctatissima*, b. *L. lisae*, c. *L. calabra*, d. *L. sicula*.

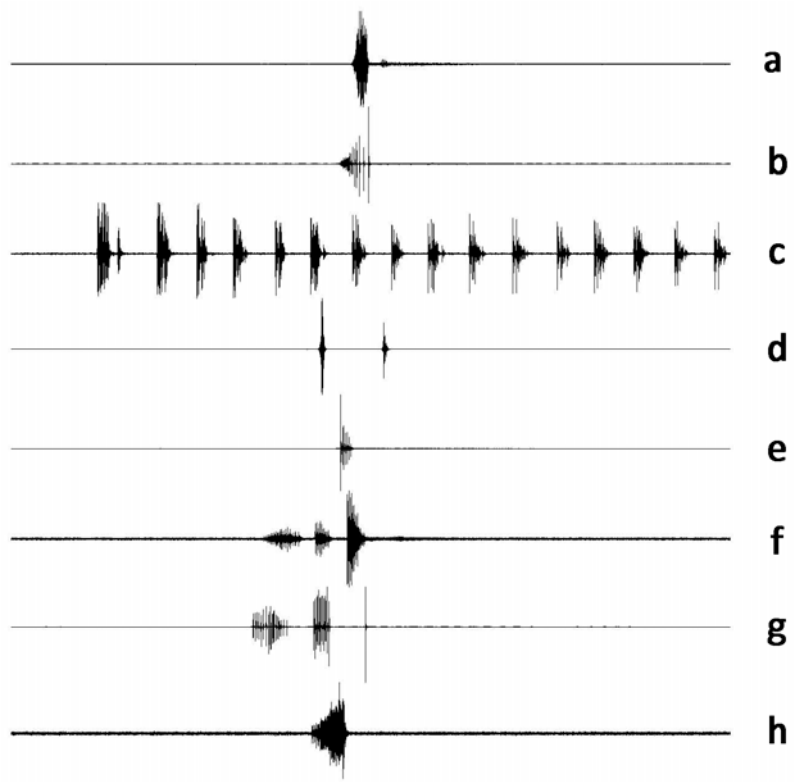

FIGURE 16. Songs of the European *Leptophyes* species, a. *L. albovittata*, b. *L. boscii*, c. *L. discoidalis*, d. *L. laticauda*, e. *L. punctatissima*, f. *L. lisae*, g. *L. calabra*, h. *L. sicula*. All recordings by Paolo Fontana or Baudewijn Odé, except *L. discoidalis* (by Sigfrid Ingrisch). Fragment of 1 sec.

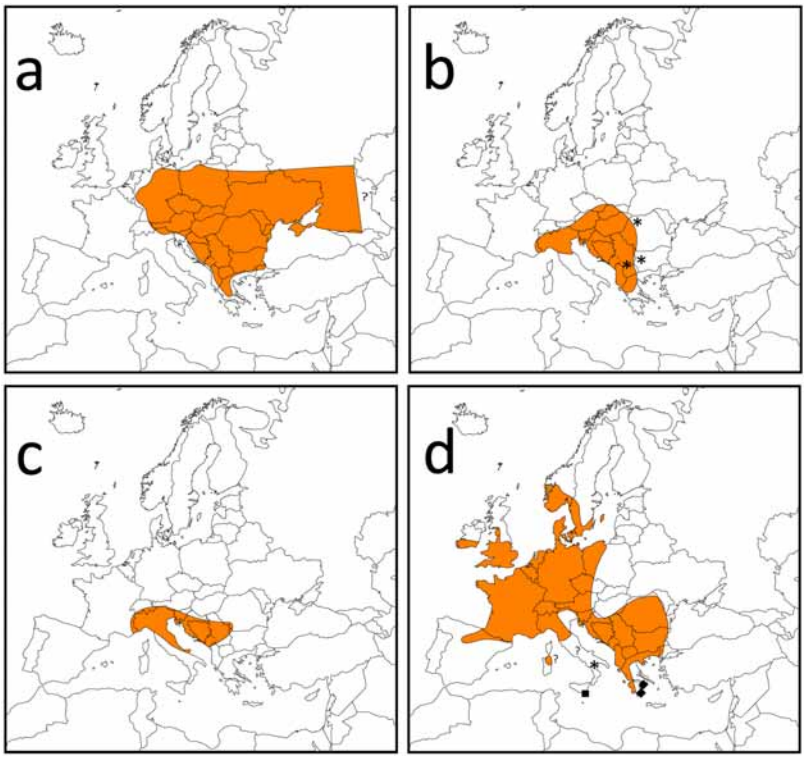

FIGURE 17. Distribution of the European *Leptophyes* species, a. *L. albovittata*, b. *L. boscii* and *L. discoidalis* (asterisk), c. *L. laticauda*, d. *L. punctatissima*, *L. lisae* (upturned square), *L. calabra* (asterisk) and *L. sicula* (square). Sources: Baur *et al.* (2006), Fontana *et al.* (2006), Harz (1969), Heller & Willemse (1989), Kleukers *et al.* (1997), Maas *et al.* (2002), Schmidt (1989, 1990), Voisin (2006).

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