SAPIENZA
UNIVERSITÀ EDITRICE

E-ISSN 2284-4880
ISSN 0429-288X

Fragmenta entomologica, 58 (1): 213–224 (2026)

Research article
Submitted: Decembre 17th, 2026 – *Accepted*: June 5th, 2026 – *Published*: June 30th, 2026
DOI: 10.13133/2284-4880/1941

Bioacoustics, morphology and conservation of the microinsular endemism of the island of Pantelleria *Gryllotalpa cossyrensis* (Orthoptera: Gryllotalpidae)

Cesare BRIZIO[1*], Paolo FONTANA[2, 1], Andrea BIDDITTU[3], Camillo A. CUSIMANO[4], Bruno MASSA[5]

[1] *World Biodiversity Association, Museo Civico di Storia Naturale di Verona, Lungadige Porta Vittoria, 9, 37129 Verona, Italy.* briziocesare@gmail.com https://orcid.org/0000-0002-7042-9684
[2] Edmund Mach Foundation, Technology Transfer Centre, 38098 San Michele all'Adige, Trento, Italy; paolo_api.fontana@fmach.it; https://orcid.org/0000-0001-9710-759X
[3] Pantelleria Island National Park, 91017 Pantelleria, Trapani, Italy
[4] Stazione Ornitologica, Monreale (Palermo), Italy; camillocusimano@gmail.com; https://orcid.org/0000-0002-3998-7549
[5] University of Palermo, Department of Agricultural, Food and Forest Sciences, 90128 Palermo, Italy; E-mail: bruno.massa@unipa.it; https://orcid.org/0000-0003-2127-0715
* Corresponding author

Abstract
After the initial presentation at the XXVIII Italian National Congress of Entomology, the peculiar song of *Gryllotalpa cossyrensis*, a microinsular endemic to the island of Pantelleria (Sicily, Italy), is here described more extensively. Unlike most of the few songs known for European species of *Gryllotalpa*, that emit uninterrupted trills, it consists of an echeme-sequence of fairly uniform echemes usually lasting around 500 msec, at a rate of around 7 every 5 sec, a pattern closely matching that by *Gryllotalpa marismortui* Broza, Blondheim & Nevo, 1998. *G. cossyrensis* lives in a very small area, namely the muddy shores of the environmentally protected Lake Bagno dell'Acqua (also known as Lago di Venere). This habitat was visited at different times of the year, and the search for juvenile and adult *G. cossyrensis* specimens did not reveal a clear phenology for the species. We hypothesize a two-year life cycle with overlapping generations as known for other *Gryllotalpa* species. However, the species' songs were only heard in June and July. *G. cossyrensis* has been classified as a vulnerable species (VU) in the European Red List of Grasshoppers, Crickets and Bush-crickets and the main problems relating to the conservation of this fragile species are described. The male genitalia and stridulatory organs of *G. cossyrensis* are described for the first time on the basis of the most modern nomenclature.

Key words: *Gryllotalpa cossyrensis*, bioacoustics, morphology, life cycle, conservation, endemism, insularity, Pantelleria Island National Park.

Introduction

Seventy-six species of the genus *Gryllotalpa* Latreille, 1802 are presently known in the world (excluding *G. algerica* Baccetti, 1987 and *G. maroccana* Baccetti, 1987, to be considered *nomina nuda*). We emphasize the fact that *G. africana* Palisot de Beauvois, 1805 is very widespread species, whose distribution also includes Europe. Fourteen species have been described in the 2000's, demonstrating the rapid growth of the systematics of this genus. Thirteen species are known in Europe, seven of which in Italy, thanks to the studies on chromosomes carried out by Baccetti & Capra (1978) and Baccetti (1991) (Table 1).

The seminal paper of Baccetti & Capra (1978) has opened up the study of *Gryllotalpa* from a different perspective, namely through the number of chromosomes. It is interesting to note that while it was originally believed that Italy hosted just one species (*G. gryllotalpa*), chromosome analysis has revealed that there are at least seven, collectively and informally referred to as *Gryllotalpa* supersp. *gryllotalpa* (Linnaeus, 1758), e.g., by Cigliano et al. (2025) based on the concept as defined by Nevo et al. (2000), who at page 587 state that "The mole crickets of Europe and the Mediterranean region, classically designated *Gryllotalpa gryllotalpa*, form a superspecies complex of fossorial insects comprising at least seven largely

Table 1. List of European species of *Gryllotalpa* with type locality.

FAUNA EUROPAEA: 13 species (7 in Italy)
G. africana Palisot de Beauvois, 1805 (type locality: KwaZulu-Natal, Mkuze Game Reserve)
G. cossyrensis Baccetti & Capra, 1979 (type locality: Italy, Sicily, Pantelleria, Lake Bagno dell'Acqua)
G. gryllotalpa (Linnaeus, 1758) (type locality: Europe)
G. krimbasi Baccetti, 1992 (type locality: Greece, Aegean, Kos Island)
G. octodecim Baccetti & Capra, 1979 (type locality: Sardinia and North Italy)
G. quindecim Baccetti & Capra, 1979 (type locality: Italy, Campania, Lago Patria)
G. sedecim Baccetti & Capra, 1979 (type locality: Sardinia and North Italy)
G. septemdecimchromosomica Ortiz, 1958 (type locality: Spain)
G. stepposa Zhantiev, 1991 (type locality: Croatia)
G. unispina Saussure, 1874 (type locality: Uzbekistan, Tashkent City)
G. viginti Baccetti & Capra, 1979 (type locality: Italy, Liguria, Lavagna)
G. vigintiunum Baccetti, 1991 (type locality: Sardinia, Località Mamone, Parco di Tepilora, Foresta di Crastazza)
G. vineae Bennet-Clark, 1970 (type locality: France, Aquitaine, Dordogne)

allopatric or parapatric chromosomal species". However, the issue is not closed and should be further investigated to understand whether these are cases of polyploidy or Robertsonian mutations; significantly, in the area where *G. sedecim* and *G. octodecim* coexist, a hybrid with 17 chromosomes has been observed (Baccetti & Capra 1978). In this study, we will restrain our investigations to a unique species living along the shores of Lake Bagno dell'Acqua on the island of Pantelleria (Sicily, Italy) that can be considered a microinsular neo-endemism. We also recorded the song of this species, which is very different from that known for *G. gryllotalpa*. We believe that the comparison of the songs of the Italian species will be very useful to better understand the species affinities in this genus.

This paper is a follow-up to the presentation delivered on 17 June 2025 by author P. F. at the XXVIII Italian National Congress of Entomology (CNIE 2025) under the title "*Gryllotalpa cossyrensis* Baccetti & Capra, 1978 endemismo microinsulare del Lago di Venere a Pantelleria (Orthoptera Gryllotalpidae)".

Methods

Field work

As part of entomological and ornithological research carried out for the Pantelleria Island National Park, several visits were made to Lake Bagno dell'Acqua (also called Venere) in search of specimens of *Gryllotalpa cossyrensis* Baccetti & Capra, 1978, a species presently known only from the muddy banks of this body of water located in the northern part of the island of Pantelleria. Since this is an endemic species living in a very limited area, invasive capture techniques (pitfall traps, etc.) and overly intensive research was avoided, so as not to compromise a population of unknown size and in any case certainly limited. The searches for specimens, conducted during the daytime, took place in 2022 (5 May, 5 July and 2 November), 2023 (29 May), 2024 (9 July and 14 September), and 2025 (27 February, 26 June, 27 October, and 3 December). During some of these visits, juveniles and adults were observed, some of which, based on permits issued by the Pantelleria Island National Park, were collected and reared. In addition to daytime surveys, since 2021 night-time PAM (Passive Acoustic Monitoring) sessions have also been conducted to record the species' acoustic activity, for 24 hours or between 9:00 PM and midnight, in continuous mode or for 30 minutes every hour. Such PAM surveys to monitor the songs of *G. cossyrensis* took place in 2021 (9-10 April), 2022 (19-21 March, 20 April and 05-06 July), 2023 (19-21 February, 5-7 and 29-30 May), 2024 (7 July and 14-15 September), and 2025 (27 February, 26-27 June, and 27-29 October).

Terminology of the parts of the phallic complex and symbol explanations in the Figures

Phallic complex nomenclature was made following and modifying Gorochov (1984, 1995), Ingrisch (1990, 2006) and Cadena-Castañeda (2015). Some synonyms of the structures, contributed by other authors, are elaborated upon within parentheses. The genital nomenclature used in the Fig. 4 is as follows (in alphabetical order):

Amp (Apex of median prolongation): Apical portion of the MP, varies in shape among the different genera of the family. This structure is hooked along with Ts in the internal genital region of the female.

Ats (Apex of transversal sclerite): Distal region of Ts, varying in shape in the different taxa of the family. It expands to attach itself in the female genitalia when mating. (=Epiphallic invagination, IE).

Bmp (Base of median prolongation): Peduncular region of MP, usually of tubular form, varying in size and shape in the different genera of the family.

Bts (Base of transversal sclerite): Proximal region of Ts, of pedunculate shape.

Ect (Ectophallus): Inferior plate of the phallic complex, made of two main structures: basal plate and the parameres. Identified structures of this genital section are:

Epi (Epiphallus): Superior plate of the phallic complex, made of two main structures: the transversal sclerite with its divisions and the median prolongation. Identified structures of this genital section are:

Ip (Internal prolongations): Disto-dorsal prolongations of the parameres, with variable shapes in the different taxa of the family.

MP (Median prolongation): Tubular structure located in the dorsal side of the phallic complex, tightly connected to the pg and ej. Ventrally, it connects with Ts and the spermatophore sac conduit. (=Epiphallus s. s.: Dessuter, 1990; =Pseudoepiphallus: Desutter-Grandcolas, 2003).

Par (Parameres): Prolongations originated in the Bp, converging in the ventral side of the phallic complex. Their functions, as is the case with Ts, is to hold the phallic complex in the female genital papilla during mating.

Ts (Transversal sclerite): Lateral prolongation of the epiphallus, of great width, curving progressively in the dorsum of the genitalia, so it can be attached when mating.

Sound recording and bioacoustics analysis hardware and software

Recording equipment included a smartphone (Galaxy A/SM-A750FN 2018) operating at a sampling frequency of 48 kHz (recorded band: 0-24 kHz) using the application Voice Recorder (Samsung Electronics Co., Ltd., version 21.3.50.34) and a "Wildlife Acoustics" model "Song Meter Micro" PAM recorder with integrated microphone, which was hidden in the vegetation. The PAM recorder sampling frequency was set to 44.1kHz (Massa et al., 2022) and programmed to record an audio file remotely. Probably due to the frequently windy conditions, both during the day and at night the PAM recordings were unsuccessful.

Figure generation and analysis were performed by Adobe Audition 1 and, limited to the calculation of Q, by the R package Rthoptera (Rivas et al., 2025). The mean spectra (Frequency/pressure analyses) were generated by scanning the entire interval of time considered and averaging pressure data through the interval - punctual distribution of pressure in each tempuscule is considered as uninformative. Adobe Audition was used to support the entire analysis workflow, including the application of frequency filters usually set at the maximum available order to ensure the steepest slope of the frequency selection function.

Results

Family Gryllotalpidae Leach, 1815
Subfamily Gryllotalpinae Leach, 1815
Genus *Gryllotalpa* Latreille, 1802
Gryllotalpa cossyrensis Baccetti & Capra, 1978
Gryllotalpa cossyrensis Baccetti & Capra 1978: 431; Baccetti, Massa & Canestrelli: 170
Massa & Rizzo, 1998: 275; Ingrisch, Nikouei & Hatami 2006: 201; Massa 2009: 78; Massa et al. 2012: 360; Iorio et al. 2019: 344.
Type locality. Europe, Italy, Sicily, Pantelleria, Lago Bagno dell'Acqua (also named Lago di Venere)
Kind of type. Male holotype, female allotype and 8 paratypes (3 males and 5 females).
Type depository. Museo Civico Storia Naturale di Genova.

Phenology

As summarized by Table 2, the adults can be encountered between the end of February through December, although this is by no means conclusive, given it is based on short-visit snapshot data. The nymphal phase was recorded in the months of June 2025, July 2024, November 2022 and December 2025. During these surveys, several juvenile stages were found, such as sub-adult individuals but also early stages.

Adults observed in July would have presumably been the result of eggs laid in the previous year. Given that advanced nymphal stages were also encountered early November and December, it may be plausible to assume that *G. cossyrensis* may indeed overwinter as an adult (potentially, along with advanced instar phases of the species). A

Table 2. Seasonal observations of life stages and stridulation.

Month	Date	Adult	Nymphs	Song
February (Baccetti & Capra, 1978)	25/II/1979	**Yes**	n/a	n/a
February	27/II/2025	**Yes**	no	no
May	29/V/2023	no	no	no
June	26/VI/2025	**Yes**	**Yes**	**Yes**
July	05/VII/2022	no	no	no
July	09/VII/2024	**Yes**	**Yes**	**Yes**
September	14/IX/2024	no	no	no
October	05/X/2022	**Yes**	no	no
October	27/X/2025	**Yes**	no	no
November	02/XI/2022	no	**Yes**	no
December	03/XII/2025	**Yes**	**Yes**	no

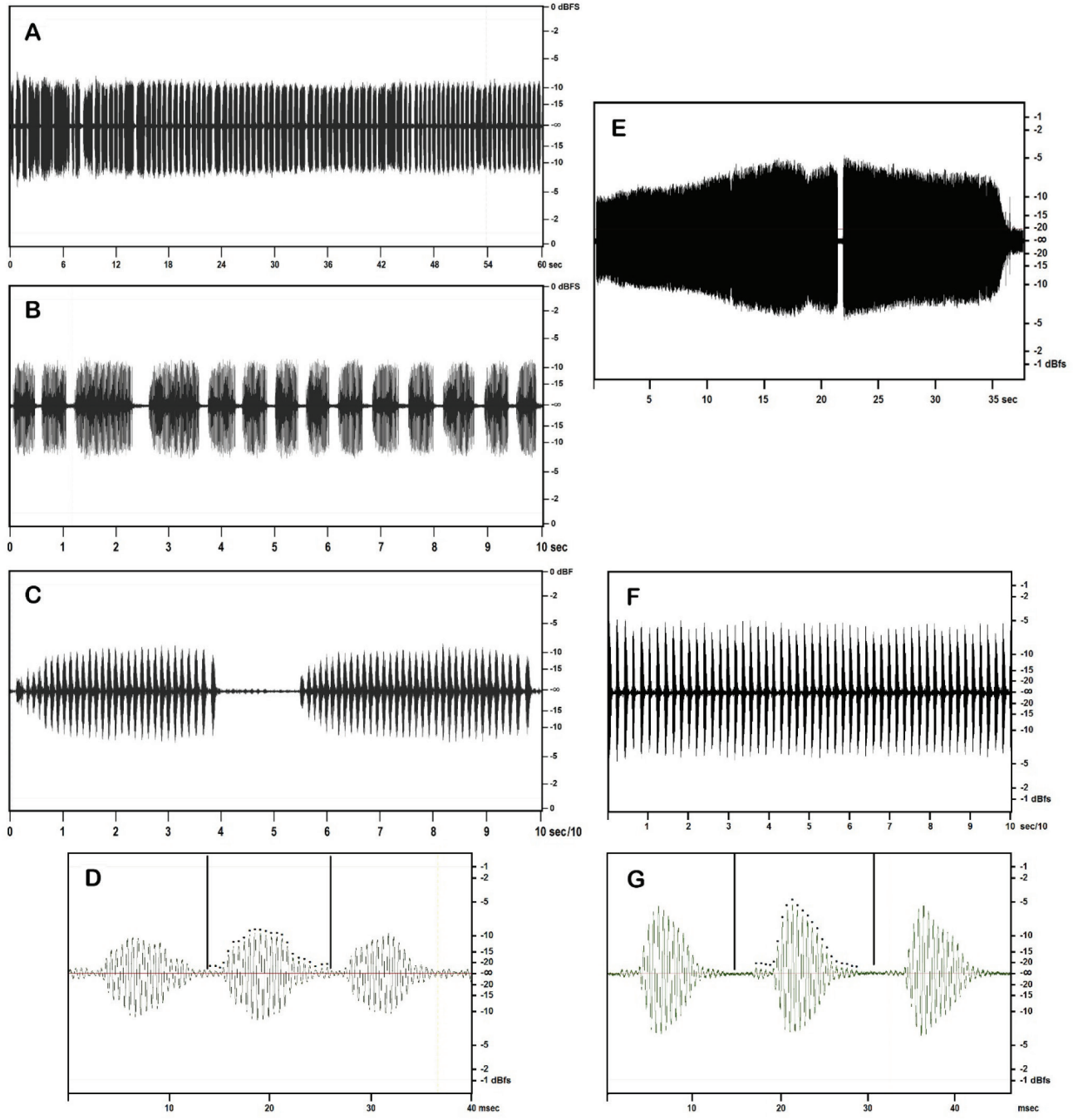

Fig. 1 – Time-Pressure Envelopes. *Gryllotalpa cossyrensis*, recorded in Pantelleria on 9 July 2024 at 22:57 local time. A, 60 s; B, 10 s; C, 1 s; D, 40 ms. *Gryllotalpa gryllotalpa*, recorded in San Pietro in Casale (Bologna, Italy) on 29 May 2018 at 23:52 local time. E, 35 s; F, 1 s; G, 50 ms. E and F from Brizio et al., 2020.

biennial biological cycle is known for some *Gryllotalpa* species such as *G. gryllotalpa* (Chopard, 1951; Servadei et al., 1972).

Song description

On 9 July 2024, starting at 22:25 local time, eight recordings were obtained with the smartphone described above. Among them, only two (respectively, lasting one minute and 30 seconds) were of sufficient quality for a song analysis. Apparently, probably due to the settings of the recording software of the smartphone, frequencies above 10 kHz were not recorded. The song description provided here is susceptible to improvements as soon as new recordings obtained with dedicated equipment will emerge.

After a thorough observation of the spectrogram, having noticed no trace of song structure attributable to the singing cricket under 700 Hz, the songs were high-pass

filtered above that frequency to suppress wind noise and distant anthropogenic sounds.

Pressure history in the time domain (sound pressure envelopes, also known as waveforms or oscillograms) is here illustrated in Fig. 1 A−D at the scale of 1 min, 10 sec, 1 sec and 40 msec for *G. cossyrensis*. For comparison purposes, Fig. 1 also includes 35 sec, 1 sec and 50 msec oscillograms of the song of *G. gryllotalpa* recorded in San Pietro in Casale (Bologna, Italy) on 29 May 2018 at 23:52 local time (E−G, E and F from Brizio et al., 2020).

With reference to the terminology by Baker and Chesmore (2020), the song of *G. cossyrensis* is an interrupted echeme-sequence of echemes usually emitted with fairly uniform duration around 500 msec, at a rate of around 7 echemes every 5 sec.

Interspersed in the echeme sequences, occasionally (up to five / seven times per minute) couples or triplets of longer echemes were observed, immediately after which, occasionally, a shorter (around 150 msec) echeme is emitted. The longer echemes in a couple/triplet are subequal and decidedly longer than in the regular song. Longest echeme duration observed was 1.8 sec.

The syllables in the echeme are emitted at a rate of around 80 per sec, with a relatively slow increase of pressure in the first 10-12 syllables, and the subsequent ones subequal. The echemes end abruptly, with a slight decrease of volume observed only in the last very few syllables. Each syllable comprises around 23 impacts, that occur at a rate of around 2 per msec. Intervals, normally lasting around 150 msec, may occasionally extend up to around 400 msec. More under, further comments about song microstructure will be provided in a comparison with the song of *G. gryllotalpa*.

For what concerns the frequency domain, as illustrated in Fig 2, the song is decidedly high-Q, as expected for any *Gryllotalpa*. Subjectively, the rather dull timbre perceived by the unaided ear is similar to that of *G. gryllotalpa* from the Padan Plain, with the obvious distinction that the song by *G. cossyrensis* is interrupted instead of continuous. Disturbances, including far bird songs and anthropogenic noises surviving the high-pass filtering, and extending up to 1300 Hz, suggest to set that frequency as the bottom of the frequency/pressure analysis window. The second harmonic frequency is the last harmonic appearing in the spectrogram and in the frequency/pressure analysis, performed with an FFT window size of 8192 samples (4096 bands). The fundamental peak of pressure is observed at 1828 Hz. First and second harmonic frequencies coincide with pressure peaks at 3603 Hz and 5431 Hz respectively, in good accordance with the fundamental. Both the fundamental and the harmonic peaks are quite blunt, preceded and followed by accessory pressure sub-peaks on each slope, resulting in wide ribbon-like bands in the spectrogram.

The recordings available to the authors include the typical song of the Padan populations of *G. gryllotalpa*, described in Fig. 1 E, F (from Brizio et al., 2020) and G, as well as in Fig. 2 C and D, obtained with wide-band recording equipment (including an Ultramic 250 USB microphone and a

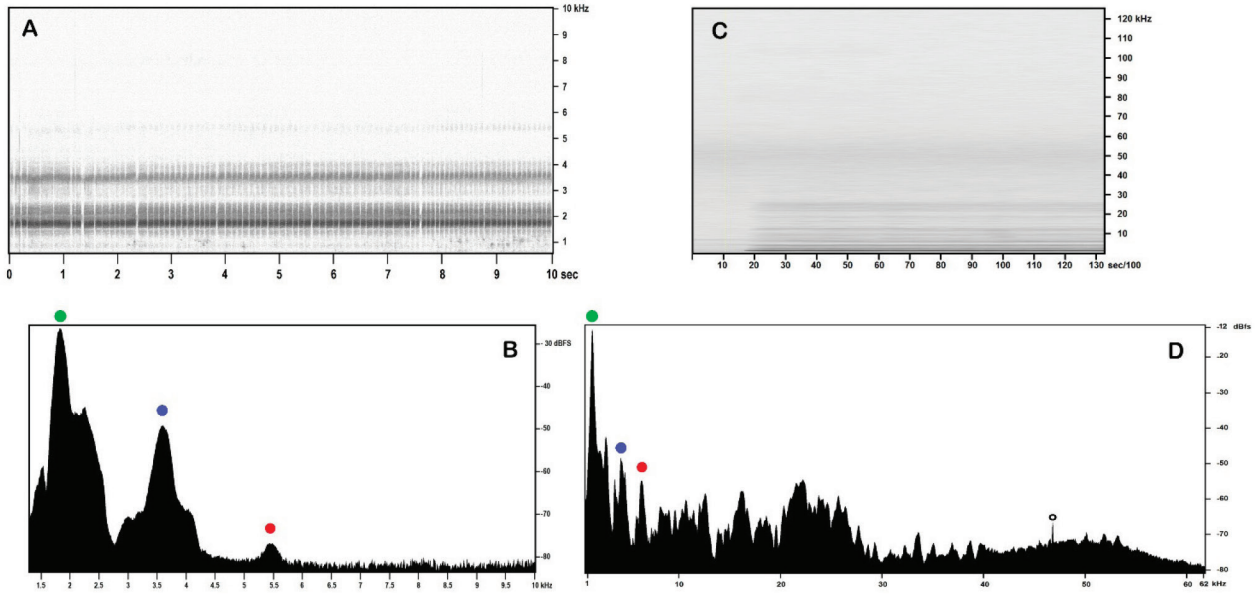

Fig. 2 – *Gryllotalpa cossyrensis*, recorded in Pantelleria on 9 July 2024 at 22:57 local time. A, time/frequency spectrogram (10 s); B, frequency/pressure analysis of the same excerpt. *Gryllotalpa gryllotalpa*, recorded in San Pietro in Casale (Bologna, Italy) on 29 May 2018 at 23:52 local time. C, time/frequency spectrogram (1.3 s); D, frequency/pressure analysis of the same excerpt. Equal color dots mark homologous peaks in the frequency-pressure analyses. C and D from Brizio et al., 2020.

portable computer) and covering also inaudible frequencies up to 125 kHz. It was recorded in the late evening of 29 May 2018 at an unreported but much lower air temperature than that observed in Pantelleria. In that occasion, the fundamental peak was observed to reach maximum pressure at 1434 Hz, with syllables emitted at a rate of around 52 per second. Such data are compatible with those by *G. cossyrensis*, considering the different temperature condition.

By zooming to an interval of a few hundredth of a second, engaging three syllables (in the acceptance of Baker & Chesmore, 2020 "first-order assemblage of tooth impacts"), the tooth impact count in each syllable can be observed and is illustrated in Fig. 1 D (*G. cossyrensis*) and G (*G. gryllotalpa*). Remembering that not all the teeth are struck with each wing closure during singing by Orthoptera (Walker & Carlysle, 1975; Toms, 1987; Hoffart, 2022), we can observe that for *G. gryllotalpa*, whose stridulatory file includes approximately 87 teeth (Jafari et al., 2015), the count of clearly marked tooth impacts per syllable as observed in the Padan specimens ranges between 20 and 25. In *G. cossyrensis*, whose stridulatory files also includes around 87 teeth, the tooth impact count per syllable amounts to around 23.

Table 3 shows the quality factor Q for the songs of *G. cossyrensis* and *G. gryllotalpa* whose mean spectra appear in Fig. 2.

The song of *Gryllotalpa marismortui* Broza, Blondheim & Nevo, 1998, the only other *Gryllotalpa* species in the Mediterranean area capable to deliver interrupted songs, deserves being cited for comparison. Unfortunately, Broza et al. (1998) did not make publicly available any audio file of the song, and the description they provide is concise. Considering the data provided in the species description and their Figure 3, also including a very few details, we can assume that *G. marismortui* usually emits uninterrupted echeme-sequences of echemes with a fairly uniform duration around 300 msec, at a rate of around 12 echemes every 5 sec, with syllable count between 17 and 24 syllables (Figure 3 in Broza et al., 1998), even though a higher variability (35.4 ± 18,4) is reported in the species description. Those data refer to a recording taken at an air temperature of 29°, probably higher than the unreported temperature in Pantelleria during the recording of the *G. cossyrensis* songs described above. Female species-specific response song was observed when playing back the *G. cossyrensis* songs. Both the fundamental frequency of around 1840 Hz and the rate of around 85 syllables per second match well the song of the Pantelleria endemite, while the syllable count in the echemes of *G. marismortui* seems to be more variable. Despite such similarities, the differences in phenology (see the Discussion) suggest caution in assuming common ancestry.

Table 3. Q-factor comparison between *G. cossyrensis* and *G. Gryllotalpa*, 1 second excerpts in Fig. 1 C and F. Calculations were performed with the R package Rthoptera (Rivas et al., 2025).

Species	Threshold		
	Q @ -3 dBfs	Q @ -10 dBfs	Q @ -20 dBfs
Gryllotalpa cossyrensis	**14.7**	**7.4**	**4.5**
Gryllotalpa gryllotalpa	**12**	**9.6**	**3.4**

Stridulatory file and phallic complex

Fig. 3 shows the stridulatory file under the left and right tegmina. Interestingly, the number of teeth on the left tegmen is below 90, consistent with what observed for *G. gryllotalpa* by Jafari et al, 2015 (see also Baccetti & Capra 1978).

Concerning the phallic complex, it was already depicted by Baccetti & Capra (1978), who highlighted the peculiar shape of median prolongation (Amp); also, parameres (Par) are peculiar (see Fig. 4).

Conservation

Gryllotalpa cossyrensis has been classified as a vulnerable species (VU) in the European Red List of Grasshoppers, Crickets and Bush-crickets (Hochkirch et al., 2016) mainly due to the extremely limited range in which the species is known and its concomitant insularity. The distribution range of *G. cossyrensis*, currently known with certainty only from the muddy shores of Lake Bagno dell'Acqua (also known as Lago di Venere), is extremely limited and coincides with areas subject to various environmental restrictions, such as:

Area 1 of the Pantelleria Island National Park;

SAC ITA010020 "Pantelleria Island – Coastal Area, Cliffs and Bagno dell'Acqua";

SPA ITA010030 "Pantelleria Island and surrounding marine area".

Furthermore, *G. cossyrensis* occurs in habitats worthy of protection, such as priority habitat 1510 "Mediterranean salt steppes – Limonietalia" and no-priority habitats 1410 "Mediterranean halophilous meadows" and 3140 "Calcareous oligomesotrophic waters with benthic vegetation of *Chara* spp." described in art. 1, paragraph d) of Directive 92/43/EEC "Habitats" as habitats at risk of disappearing in the territory under consideration and for whose conservation Member States are required to designate special areas of conservation. See Figs. 5 and 6 for a panoramic view of the area and for details of the burrows.

The Mayoral Ordinance No. 95 of June 29, 2023, regarding the protection of Lake Bagno dell'Acqua aims to protect and conserve the specific habitat of *G. cossyrensis*, with an attempt to manage the significant tourist flows that affect the lake itself. Commercial promotion of the island focuses on the lake as a spa and a destination when sea conditions are unsafe for bathing, resulting in significant human pressure on this geological site. We also document photographically one instance of predation of this mole cricket by a Squacco Heron *Ardeola ralloides* (Fig. 7).

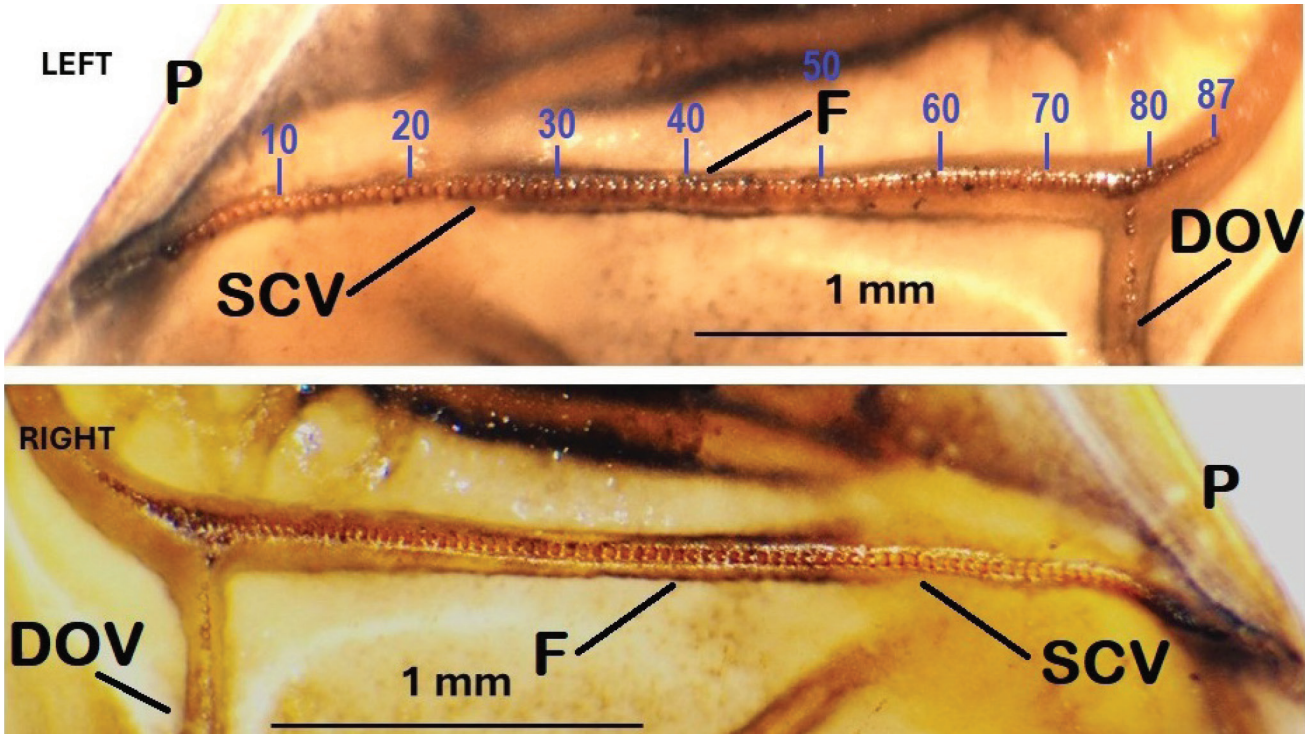

Fig. 3 – Stridulatory file under the left and right tegmina of *Gryllotalpa cossyrensis*. DOV – Distal Oblique Vein; F – Stridulatory File; SCV – Second Cubital vein; P – Plectrum; the 1 mm scale reference marks the Harp area; Blue marks along the stridulatory file mark teeth count increments.

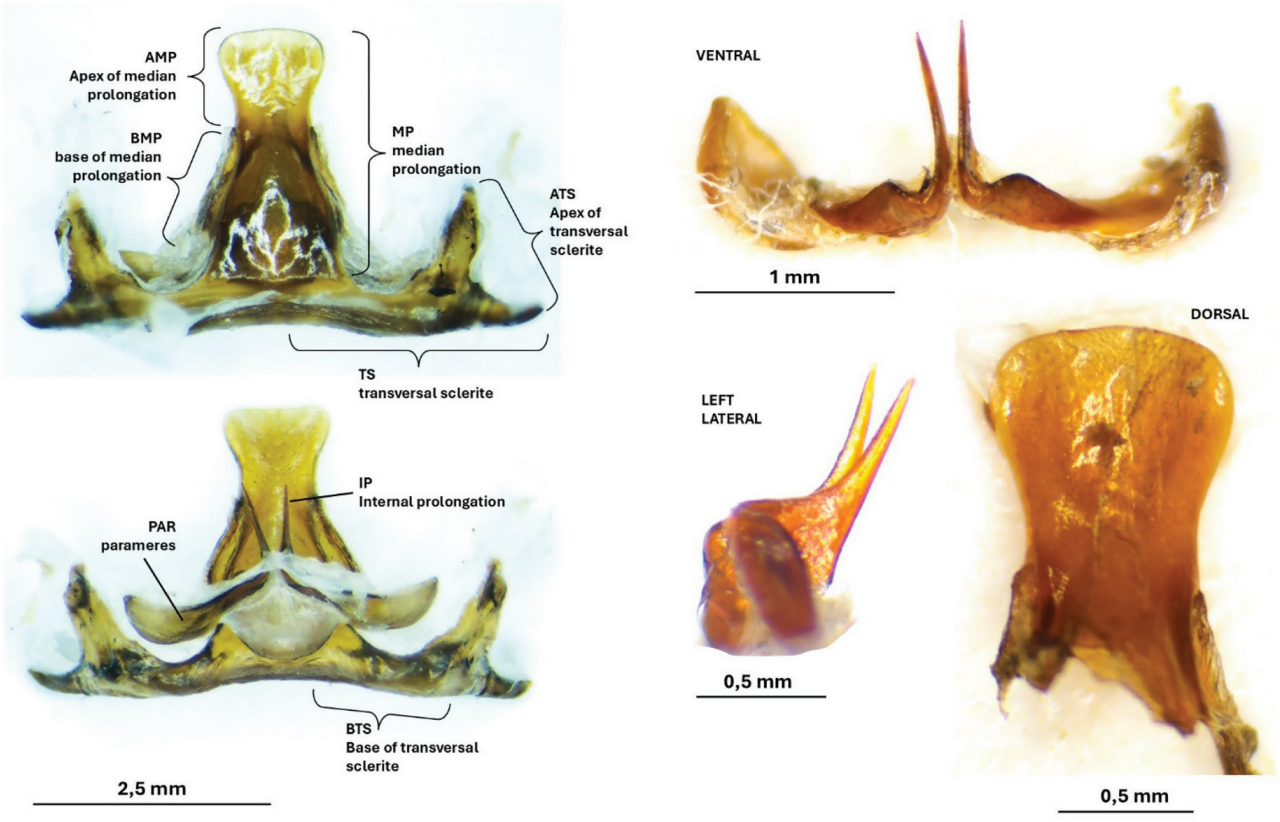

Fig. 4 – Phallic complex of a male of Gryllotalpa cossyrensis from Lago Bagno dell'Acqua (Pantelleria, Italy).

All things considered, based on the available information, *G. cossyrensis* would better fit in the EN (Endangered) or in the CR (critical) category.

The Pantelleria Island National Park was established recently (2017) and does not yet have a Regulation and Park Plan that would address the site's comprehensive protection in a uniform and effective manner. Much is being done in the field of environmental education, disseminating the geological, biological, and historical reality of the lake to the younger population, and in the field of scientific research, with many researchers and scholars monitoring and reporting on the species and biological communities unique to the area.

Discussion

Generally speaking, the bioacoustics of the genus *Gryllotalpa* is still poorly known and under-investigated, and is complicated by the low or null phenotypical interspecific variability within species clusters such as *Gryllotalpa* supersp. *gryllotalpa* (Linnaeus, 1758). Despite our best effort, we weren't able to locate songs attributed with certitude to such Italian superspecies members that can be separated only by the chromosomal equipment (all by Baccetti & Capra, 1978 unless otherwise noted) as *G. quindecim*, *G. sedecim*, *G. septedecimchromosomica* Ortiz, 1958, *G. octodecim*, *G, viginti* and *G. vigintiunum* Baccetti, 1991: we currently have no proof that their song can be distinguished from that of 12-chromosomes, long winged *G. gryllotalpa*, and it's equally impossible to ascertain the chromosome count of the specimens that emitted the songs generically attributed to *G. gryllotalpa* in the online repositories. In this uncertain scenario, the centerpiece of our study, the previously unreported song of *G. cossyrensis* and the song of *G. marismortui* as described by Broza et al. (1998) emerge as exceptions: while the other Mediterranean *Gryllotalpa* deliver songs consisting of uninterrupted echeme-sequences, with a fundamental frequency peaking at around 1.5 kHz (the only exception being *G. vineae*, whose fundamental is one octave above that by typical *G. gryllotalpa*) the Pantelleria endemite and *G. marismortui* emit separate, well-spaced echemes, as exhaustively described in the Results section.

The obvious difference in the temporal patterns of the song prompted us to investigate whether physical constraints such as anatomical differences can account for the different song delivery. As reported in the Results section, we didn't notice any relevant difference between the stridulatory apparatus of *G. cossyrensis* (Fig. 4) and that of *G. gryllotalpa*, so we compared the spectral analyses of their songs, illustrated in Fig. 2.

By zooming in on the first three peaks of Fig. 2 D, it's readily evident that – regardless to the temperature-induced frequency shift – the harmonic structure in the two

Fig. 5 – Above: Habitat of lago Bagno dell'Acqua of Pantelleria; below: typical tunnels excavated by *Gryllotalpa cossyrensis* along the shores of the lake.

species of *Gryllotalpa* coincides, with different accentuation of the subpeaks depending on the radically different sampling frequency and dynamic response of the microphones used respectively in Pantelleria and in San Pietro in Casale. Same color dots mark the homologous peaks in the mean spectra. Consequently, again taking into account the different equipment, the calculation of quality factor Q (Table 3), delivers consistent results in the two species: only at a threshold of -10 dBfs a slightly lower Q is observed, due the slightly lower kurtosis and the asymmetrical sloping of the main pressure peak in *G. cossyrensis* (both are possible side effects of the higher low-frequency response of the microphones used in Pantelleria).

The main and striking difference between, on one side, *G. cossyrensis* and *G. marismortui* and, on the other side, the other Mediterranean *Gryllotalpa* song is surely the emission of short and quite regular echeme-sequences ("chirps") instead of the continuous, uninterrupted echeme ("trill") typical of the genus and observed e.g. in *G. gryllotalpa* (and related species) from the Italian mainland as well as in *G. vineae* from France. In that respect, the non-continuous songs resemble those of the American Prairie mole cricket *G. major* Saussure, 1874 and of the Northern mole cricket *Neocurtilla hexadactyla* (Perty,

Fig. 6 – Above: Adult male of Gryllotalpa cossyrensis; below: 2nd instar nymph of the same along the shores of Lago Bagno dell'Acqua of Pantelleria.

Fig. 7 – *Gryllotalpa cossyrensis* preyed on by a Squacco heron *Ardeola ralloides* at Lago Bagno dell'Acqua of Pantelleria (Photo by P. Ferrandes).

1832) (Hoffart et al., 2002). Other analogies may be found with the interrupted songs of the Australian *Gryllotalpa pluvialis* (Mjöberg, 1913) and of the Malgasy *Gryllotalpa madecassa* (Chopard, 1920).

According to Otte (1992), trills are the commonest form of song in cricket species and, as pointed out by Alexander (1962), represent the ancestral condition, while the less energetically expensive chirping may evolve from the ecological constraints present in colder, drier or less hospital native habitats. Besides that, chirping – by providing silent intervals between echemes or echeme-sequences – may allow a singing individual to assess the presence of competing homospecific songs during its song bouts, an advantage that may be negated by continuous or long-lasting trills.

Another relevant song-related feature is the availability of an ambidextral fully-developed soniferous apparatus. Contrary to most Ensifera, as observed, e.g., by Kavanaugh and Young (1989) for the Australian mole cricket *G. australis* Otte & Alexander, 1983, Gryllotalpidae may be able to call with both forewings. In fact, when Forrest (1987) examined males and females of Tawny mole cricket *Neoscapteriscus borellii* (Giglio-Tos, 1894) and Southern mole cricket *N. vicinus* (Scudder, 1869), he found that their use of right or left forewing on top did not substantially differ from 50-50. Contrary to the hypothesis of an ancestral ambidexterity, he suggested that calling from a position where the wings rubbed against the roof of the burrow may have constituted a selective pressure for the alternate use of wings in calling.

The implication of such findings is that there is no relevant difference in the anatomy nor in the use of the stridulatory apparatus between the two species of *Gryllotalpa*, in accordance with Hoffart et al. (2002) who conclude that call type in mole crickets does not appear to be constrained by the morphology of the stridulatory apparatus. Consequently, the reason for the emergence of a song pattern different from that of the species from the European mainland is purely behavioral and can most probably be attributed to the ecological constraints of the insular scenario of Pantelleria.

The investigation of the song of *G. cossyrensis* provided the opportunity to collect samples for a novel molecular genetics study, currently under way. Pending its results, we remind the reader that describing this species, Baccetti & Capra (1978) highlighted the similarity with the "Dead

Sea race" of *G. gryllotalpa* (which has the same number of chromosomes), later described as *G. marismortui*, a species living in the Dead Sea in similar ecological conditions of Lago Bagno dell'Acqua of Pantelleria (very salty and moderately hot water). Broza et al. (1998), well aware of the similarities, provide an exhaustive list of the morphological differences between the two species: while some morphometric measurements overlap, they deviate completely in the shape and ratio of length of cell 1/cell 2 of the male fore wing. The segment Z (see Baccetti & Capra, 1978) of vein Cu1 (and cell 2) is much smaller than X of Cu1 in *G. marismortui*, in contrast to *G. cossyrensis*. Cell 1 in *G. cossyrensis* is r-shaped, in contrast to the straight cell of G. marismortui (Fig. 2). Analytical comparison of the cuticular hydrocarbons of the two populations (Broza & Nation, unpublished data) supports the present conclusion that they are indeed two species, in contrast to the remark of Baccetti & Capra (1978).

In addition, Baccetti & Capra (1978) found some similarities with specimens of *Gryllotalpa* from Libya and Tunisia preserved in the Museum of Natural History of Genoa. Later Baccetti (1987) coined two new names, *Gryllotalpa algerica* and *Gryllotalpa maroccana*, without any detailed description besides the photo of spermatozoa. For these two taxa, which should be considered *nomina nuda*, no other information is available. Considering the long distance between Pantelleria and the Dead Sea, it's very probable that the two taxa share no other affinity besides the number of chromosomes and the peculiar habitat. We believe that the song of the two species is similar probably due to a case of evolutionary convergence, possibly dependent on particular environmental conditions.

Concerning the possibility that *G. cossyrensis* could live also in North Africa, we cannot rule it out, but we believe it's more likely that the Pantelleria species is neo-endemic, originating from a few *Gryllotalpa* that arrived on the island by chance and evolved in a very peculiar environmental condition. A similar case is that of *Acheta pantescus* (see Massa et al., 2023).

Conclusions

Overall, according to our present knowledge, *G. cossyrensis* lives only along the shores of Lago Bagno dell'Acqua of Pantelleria and could be considered a neo-endemic taxon of this island, probably very threatened by the human impact on the shores of the lake.

Its song, consisting of discrete echemes, is one of the two known exceptions (the other being G. *marismortui* from Israel, a species whose differences with *G. cossyrensis* were exhaustively described by Broza et al., 1998), among the uninterrupted trills of its Mediterranean congenerics, and can be compared with that by other, most probably unrelated *Gryllotalpa* species from other parts of the world. The peculiarity of the song of *G. cossyrensis* does not emerge from any observable anatomical difference, is of behavioral nature and most probably arose independently in the Pantelleria endemite, in *G. marismortui* and in the other American, African and Australian species as a selectively advantageous evolution of the ancestral continuous trill.

More molecular genetics, morphological and bioacoustics studies about mole crickets are still needed to ascertain the actual status of the genus *Gryllotalpa* in Italy. Regarding *Gryllotalpa cossyrensis*, it will be useful to identify its diet, better define its phenology, verify its presence in other sites on the island, make a comparison with populations in the Mediterranean basin and adopt a specific and effective protection plan.

With particular reference to *G. marismortui*, we concur with Broza et al. (1998) who observe that it would be important to find and describe the internal structure of the singing burrows of both species, as Bennet-Clark (1970, 1987) emphasized that the singing burrows are species-specific.

Acknowledgements

We thank the anonymous reviewers for their insightful comments. Some observations on *Gryllotalpa cossyrensis* were possible thanks to activities carried out during the Monitoring of Breeding Seabirds in the Sicilian Region, coordinated by Tommaso La Mantia (University of Palermo, Department SAAF) on behalf of Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA); we would thank very much T. La Mantia who involved us in this research. Sara Chiarello, Simone Costa, Marco Pecoraro, Louis Cassar shared with BM and CC some visits to Pantelleria. We would like to thank very much Pietro Ferrandes for making his photo of Squacco Heron available to us.

References

Alexander R.D. 1962. Evolutionary change in cricket acoustical communication. Evolution, 16: 443–467, Doi: https://doi.org/10.2307/2406178

Baccetti B. 1987. Spermatozoa and phylogeny in orthopteroid insects. Pp. 12–112 in: Baccetti (ed.), Evolutionary Biology of Orthopteroid Insects. Ellis Horwood Ltd., Chichester, England, 612 pp.

Baccetti B. 1991. Ricerche zoologiche della Nave Oceanografica 'Minerva' (C.N.R.) sulle Isole circumsarde. 10. Insetti ortotteroidei (Notulae orthopterologicae. 49). Annali del Museo Civico di Storia Naturale di Genova, 88: 403–479.

Baccetti B., Capra F. 1978. Notulae orthopterologicae. XXXIV. Le specie italiane del genere Gryllotalpa L. Redia, 61: 401–464.

Baccetti B., Massa B., Canestrelli P. 1995. Dermaptera, Isoptera, Blattodea, Mantodea, Phasmatodea e Orthoptera. Naturalista Siciliano, 19: 163-194.

Baker E., Chesmore D. 2020. Standardisation of bioacoustic terminology for insects. Biodiversity Data Journal 8, e54222, Doi: https://doi.org/10.3897/BDJ.8.e54222

Bennet-Clark H.C. 1970. The mechanism and efficiency of sound production in mole crickets. Journal of Experimental Biology, 52: 619–652, Doi: https://doi.org/10.1242/jeb.52.3.619

Bennet-Clark H.C. 1987. The tuned singing burrow of mole crickets. Journal of Experimental Biology, 128: 383–410, Doi: https://doi.org/10.1242/jeb.128.1.383

Brizio C., Buzzetti F.M., Pavan G. 2020. Beyond the audible: Wide band (0–125 kHz) field investigation on Italian Orthoptera (Insecta) songs. Biodiversity Journal 11: 443–496, Doi: https://doi.org/10.31396/Biodiv.Jour.2020.11.2.443.496

Broza M., Blondheim S., Nevo E. 1998. New species of mole crickets of the Gryllotalpa gryllotalpa group (Orthoptera: Gryllotalpidae) from Israel, based on morphology, song recordings, chromosomes and cuticular hydrocarbons, with comments on the distribution of the group in Europe and the Mediterranean region. Systematic Entomology 23: 125–135, Doi: https://doi.org/10.1046/j.1365-3113.1998.00048.x

Cadena-Castañeda O. J. 2015. The phallic structures in Gryllotalpidae (Orthoptera: Gryllotalpoidea), and its generic implications. Zootaxa 3981(2): 264–274, Doi: https://doi.org/10.11646/zootaxa.3981.2.7

Chopard L. 1951. Faune de France, 56: Orthopteroides. Lechevalier, Paris: 359 pp.

Cigliano M.M., Braun H., Eades D.C., Otte D. 2025. Gryllotalpa supersp. gryllotalpa (Linnaeus, 1758). Orthoptera Species File. Retrieved on 2025-12-16 at http://orthoptera.speciesfile.org/otus/837547/overview

Forrest T.G. 1987. Sinistrality in the southern and tawny mole crickets (Gryllotalpidae: *Scapteriscus*). Florida Entomologist 70: 284–286, Doi: https://doi.org/10.2307/3495161

Gorochov A.V. 1984. On the higher classification of recent Ensifera (Orthoptera). Verhandlungen des Zehnten Internationalen Symposiums über Entomofaunistik, 951–954.

Gorochov A.V. 1995. System and evolution of the suborder Ensifera (Orthoptera). Part 1 [in Russian]. Trudy Zoologicheskogo Instituta, 260 (1): 1–224.

Hochkirch A., Nieto, A., García Criado M., Cálix M., Braud Y., Buzzetti F. M., Tumbrinck J. 2016. European red list of grasshoppers, crickets and bush-crickets. Publications Office of the European Union: 88 pp., Doi: https://doi.org/10.2779/60944

Ingrisch S. 1990. Grylloptera and Orthoptera s.str. from Nepal and Darjeeling in the Zoologische Staatssammlung München. Spixiana (Munich), 13: 149–182.

Ingrisch S. 2006. Orthoptera (Insecta) fauna of the Nepal Himalayas: current knowledge. In Hartmann & Weipert. Biodiversität und Naturausstattung im Himalaya, Biodiversity and Natural Heritage of the Himalaya II: 73–118.

Ingrisch S., Nikouei P., Hatami B. 2006. A new species of mole crickets *Gryllotalpa* Linnaeus, 1758 from Iran (Orthoptera: Gryllotalpidae). Entomologische Zeitschrift mit Insekten-Börse 116(5): 195–202.

Iorio C., Roberto S., Fontana P., Buzzetti F.M., Kleukers R., Odé B., Massa B. 2019. Grasshoppers and crickets of Italy: A photographic field guide to all the species (Vol. 10). WBA Project Srl.

Hoffart C., Jones, K., Hill P.S.M. 2002. Comparative Morphology of the Stridulatory Apparatus of the Gryllotalpidae (Orthoptera) of the Continental United States. Journal of the Kansas Entomological Society 75(2), 123–131.

Jafari S., Kazemi M.H., Lotfalizadeh H. 2015. Acoustic burrow structures of European mole crickets, Gryllotalpa gryllotalpa (Orth.: Gryllotalpidae) in Northwestern Iran. North-Western Journal of Zoology 11 (1): 58–61.

Kavanaugh M.W., Young, D. 1989. Bilateral symmetry of sound production in the mole cricket, Gryllotalpa australis. Journal of comparative Physiology A 166: 43–49, Doi: https://doi.org/10.1007/BF00190208

Massa B. 2009. Annotated check-list of Orthoptera of Libya. Journal of Orthoptera Research 18(1): 75–93.

Massa B., Cusimano C.A., Fontana P., Brizio C. 2022. New Unexpected Species of Acheta (Orthoptera, Gryllidae) from the Italian Volcanic Island of Pantelleria. Diversity, 14: 802, Doi: https://doi.org/10.3390/d14100802

Massa B., Fontana P., Buzzetti F.M., Kleukers R., Odé B. 2012. Fauna d'Italia. Orthoptera, Vol. 48.

Massa B., Rizzo M.C. 1998. Orthoptera raccolti in Tunisia nel XIX secolo e conservati nel Museo Civico di Storia Naturale "G. Doria" di Genova. Annali del Museo Civico di Storia Naturale Giacomo Doria, 92: 273-292.

Nevo E., Beiles A., Korol A. B., Ronin Y. I., Pavlicek T., Hamilton, W. 2007. Extraordinary multilocus genetic organization in mole crickets, Gryllotalpidae. Evolution 54(2): 586-605, Doi: https://doi.org/10.1554/0014-3820(2000)054[0586:EMGOIM]2.0.CO;2

Otte D. 1992. Evolution of cricket songs. Journal of Orthoptera Research 1: 25–49, Doi: https://doi.org/10.2307/3503559

Rivas F., Brizio C., Buzzetti F. M., Pijanowski, B. 2025. Rthoptera: Standardised insect bioacoustics in R. Methods in Ecology and Evolution, 00: 1–11, Doi: https://doi.org/10.1111/2041-210X.70045

Servadei A., Zangheri S., Masutti L. 1972. Entomologia generale ed applicata. CEDAM, Padova: 733 pp.

Toms R.B. 1987. Speciation and taxonomic features in tree crickets (Grylloidea:Oecanthidae). In B.M. Baccetti, (ed.). Evolutionary Biology of Orthopteroid Insects, pp. 571–580. Ellis Elwood Limited, Chichester, UK.

Walker T.J., Carlysle T.C. 1975. Stridulatory file teeth in crickets: taxonomic and acoustic implications (Orthoptera:Gryllidae). International Journal of Insect Morphology and Embriology 4: 151–158, Doi: https://doi.org/10.1016/0020-7322(75)90013-6