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High frequency components of the songs of two Cicadas (Hemiptera Cicadidae) from Sardinia (Italy) investigated by a low-cost USB microphone

Cesare Brizio

CIBRA - Centro Interdisciplinare di Bioacustica e Ricerche Ambientali dell'Università di Pavia, ViaTaramelli 24, Pavia, Italy: e.-mail: cebrizi@tin.it

ABSTRACT During August 2013, a low-cost ultrasonic USB microphone (Ultramic 250 by Dodotronic), was field-tested for its first application ever in Cicadomorphan bioacoustics studies. Two different species were recorded in the ultrasonic domain, with 250 kHz sampling frequency, one of them also with 96kHz audio recordings for comparison purposes. Ultramic 250 proved suitable for field use, while the recording campaign provided the opportunity to confirm the presence in South-Western Sardinia of two species (Hemiptera Cicadidae), *Tibicina corsica corsica* Boulard, 1983, endemic to Sardinia and Corse, and the widespread *Cicada orni* Linnaeus, 1758. To the best knowledge of the author, those reported are the first field recordings of Cicadidae songs encompassing the ultrasonic domain up to 125 kHz and, in particular for *C. orni*, display sound emissions at frequencies above those previously reported in literature. Even though conceived for the study of Chiropterans, self-contained, low-cost USB ultrasonic microphones proved useful in insect bioacoustics investigations.

KEY WORDS Cicadomorpha; ultrasound; bioacoustics.

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INTRODUCTION

It has been known for several years that many insects species do hear ultrasounds, as for example in the papers by Conner (1999), Barber & Conner (2007), Pollack (2007), Nakano et al. (2008), Sueur et al. (2008), Corcoran et al. (2009), Nakano et al. (2009), Takanashi et al. (2010) and Yager (2012), that successfully demonstrate that ultrasounds play a significant role in many contexts, including prey-predator interaction and male-female communication. Despite this widely acknowledged fact, spectral components well above human hearing are seldom included in field studies about insect songs, although investigations and description of animal sounds restrained to a specific frequency window (such as the human hearing range), may result in an incomplete or improper representation of their actual harmonic structure, leading to disputable conclusions.

Generally speaking, with the notable exception of the study of Chiropterans, bioacoustics of the sub-aerial fauna, including insect sounds, has been field-studied mainly within the human hearing range (conventionally ranging from 20 Hz to 20 kHz - herein under, “audio range”), both for comparability with published materials, that we may deem as “historical anthropocentrism”, and for technical reasons including high cost and complex handling of the equipment for ultrasound recording, that may require a specific technological stack including dedicated microphones, preamplifiers, power sources and recorders, that may prove unsuitable for field use.

A recent field expedition of the author to SW Sardinia, Fluminimaggiore (Carbonia-Iglesias Province), provided the opportunity to field-test an innovative, low cost USB microphone, Dodotronic Ultramic 250, and resulted in the ultrasound recordings here presented to improve bioacoustic knowledge on local Cicadomorpha, as well as to document what appears, to the best knowledge of the author, as the first application of a new class of cheap, self-contained USB microphones with ultrasonic threshold, epitomized by Ultramic 250, in the field of Hemiptera scientific bioacoustics. As a further note of interest, the cicada fauna of Sardinia is still not particularly well studied (J. Sueur, pers. comm.), and the recordings themselves may contribute to filling this gap.

MATERIAL AND METHODS

Brizio & Buzzetti (2014) reported about the successful usage of Ultramic 250 (Fig. 1) in the field of Orthopteran bioacoustic studies. To test whether Ultramic application to Cicadomorphan bioacoustics would prove equally valid, in August 2013 two species of cicada from Sardinia were recorded.

All the species reported were recorded within a 15 km range from Fluminimaggiore (Carbonia-Iglesias Province, Sardinia, Italy) (Fig. 2), although additional recordings of *Cicada orni* Linnaeus, 1758 were subsequently taken in mainland Italy. All the audio material was obtained by field recording. Specimens were not captured nor recorded in constrained conditions.

The capability of Ultramic 250 to deliver accurate recordings of Orthopteran songs was demonstrated in a separate study (Brizio & Buzzetti, 2014), also by collecting 96 kHz, 16 bit stereo recordings for comparison purposes. Available equipment for audio recordingsincluded a Zoom H1 handheld digital Micro-SD recorder, coupled with a self-built stick stereo microphone using Panasonic WM-64 capsules from an Edirol R-09 digital recorder. Acoustic recordings were taken in stereo, 16 bit, with 96 kHz sampling frequency, and thus capable of covering frequencies up to 48 kHz.

Figure 1. Ultrasound USB recording set: Asus Eee PC 1225B notebook personal computer, USB cable and Dodotronic Ultramic 250. On the display, SeaWave software by the University of Pavia's Interdisciplinary Center for Bioacoustics.

Ultrasound monophonic recording at 250 kHz sampling frequency was performed via a Dodotronic Ultramic 250 microphone connected via USB cable to an Asus Eee PC 1225B notebook personal computer, using SeaWave software by CIBRA-University of Pavia's "Centro Interdisciplinare di Bioacustica e RicercheAmbientali" (http://www-3.unipv.it/cibra/). Originally received as amplitude data (mV) by the recording apparatus, software-normalized spectral energy is expressed in decibels. Sound pressure is expressed in dB Full Scale, even though the dB symbol will be used.

Oscillograms, spectrograms and frequency analysis diagrams were generated by Adobe Audition 1.0 software. All the illustrations refer to Ultramic 250 monophonic recordings unless otherwise noted.

In the recent paper by Brizio & Buzzetti (2014), some technical requirements of Ultramic 250 (such as the need to keep the USB cable length under 1 m) are addressed in more detail. The same paper proposes a specific operating protocol to ensure comparability between Ultramic recordings and audio range recordings available in literature, and supports the consistency of recordings obtained by Ultramic and by conventional microphones, while some cautions are needed due to the poorer frequency response of the ultrasonic-threshold microphone capsule if compared to ordinary microphones.

In day time condition unaffected by Chiropteran or Orthopteran sounds, background noise floor level in the ultrasonic domain can be empirically determined from frequency analyses as the average level of the spectral components not attributable to the sounds emitted by the recorded specimen, and can easily be measured by recording environmental sounds in quiet, no wind conditions, pointing the microphone towards the specimen during silence pauses. For the recordings here analysed, and for a "medium gain" setting of Ultramic 250 (see Brizio & Buzzetti, 2014), noise floor level in spectral frequency analyses can be placed at around -80 dB for the entire unaudible range.

In the recording station of Capo Pecora, a 71 kHz, very narrow band continuous emission up to -65 dB was recorded even in silent conditions and, being unrelated with the animal sounds here described, shall be reported but excluded from any kind of analysis and will be considered as part of the background noise, its plausible origin being telecommunication antennas in the vicinities that may directly originate the noise, or may induce a spurious harmonic component in the Ultramic circuitry.

When using Ultramic in the field, it is particularly uneasy to find the ideal recording distance from a singing specimen (even more so when, as in the case of the recordings presented here, the specimen was out of sight) for reasons that include the incapacity of the human ear to take into account the volume of the inaudible components (as a consequence, volumes perceived as relatively low by the unaided ear may saturate the recording) and the variable intensity of inaudible components during song emission. As a consequence, even the smallest variation in the direction of the handheld microphone pointing towards an unseen specimen may result in more or less sharp volume changes, that compose with the natural pattern of volume variations. Consistent with the scope of this study, the author strived to attain the closest possible range and the most precise and constant microphone heading that could provide a high volume input, as near as possible to 0 dBfs, from which even the faintest high frequency harmonics, the most directional and prone to attenuation even at relatively short distance - could be extracted and analyzed.

For those reasons, although the oscillogram, generated in real time by SeaWave, was constantly monitored during the recording, small oscillations in volume can be observed.

Adobe Audition software settings, such as resolution in bands, windowing function and

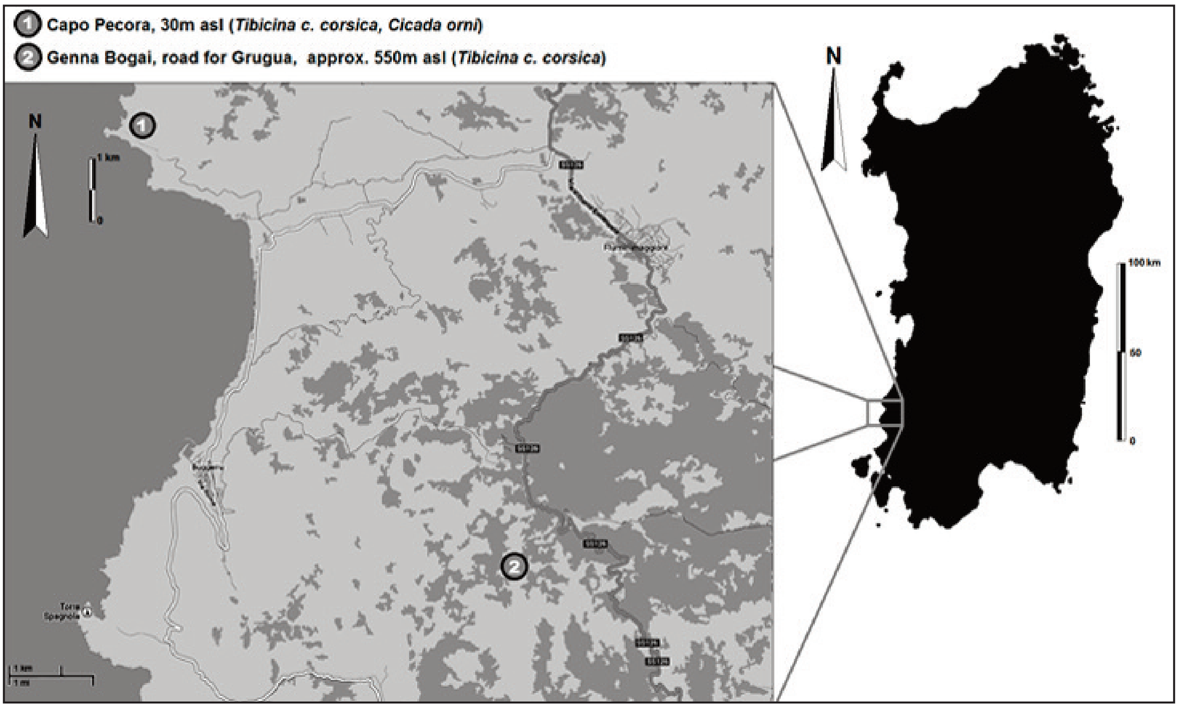


Figure 2. Recording stations in southwestern Sardinia, in the territory of the Communes of Arbus (Capo Pecora) and Fluminimaggiore (Grugua).

logarithmic energy plot range (in our case, respectively 16384, Welch Gaussian and 100 dB) used to generate time-frequency spectrograms were selected as the best compromise for an accurate graphical rendition unaffected by over-representation of background noise. As a consequence of the settings chosen, the lowest significant energy level visualized in the time-frequency spectrograms generated by Adobe Audition is around -70 dB. In all the frequency analyses, a heavy line was superimposed to the illustration at the -70 dB level (Figs. 7, 11 14), marking the level above which spectral components emerge in the time-frequency spectrograms, and constituting a very conservative threshold for the safe attribution of those components, well above the background ultrasonic noise, to the singing animal.

To give more evidence even to the faintest significant spectral components, screenshots from time-frequency spectrograms (Figs. 8, 12, 13) were contrast-enhanced with Adobe Photoshop by a procedure involving in sequence: color removal, image inversion, brightness and contrast adjustment, shadows/highlights adjustment. Those interventions did not affect the accuracy of time-frequency rendering, and allowed to highlight the 95 kHz “tail” (see below) to *C. orni* sound units.

RESULTS AND DISCUSSION

Tibicina corsica corsica Boulard, 1983

EVIDENCE COLLECTED. Bioacoustical and photographic.

Figure 3. One of the recorded specimens of *Tibicina corsica corsica*, Genna Bogai, 16.VIII.2013.

EXAMINED MATERIAL. Italy, Sardinia, Genna Bogai (Carbonia-Iglesias Province), Latitude 39.37373, Longitude 8.49732, 549 m asl and Capo Pecora (Medio Campidano Province), Latitude 39.450908, Longitude 8.396298, 20 m asl.

DISTRIBUTION. This subspecies (Fig. 3) is distributed in Sardinia and Corse (its type locality), while in mainland Europe (Southern France) it’s substituted by *T. corsica farmairei* Boulard, 1984.

REMARKS. Identification of this species, based also on visual recognition supported by photographic evidence, posed no doubt.

Ultrasound recordings took place near Capo Pecora, in the low shrubs (garrigue) with air temperatures in the range of 27 °C at around 16.00. 96 kHz recordings collected around 11 a.m., in comparable air temperature, along the road from the Genna Bogai pass to the locality called Grugua, allowed to verify the consistency between Ultramic and ordinary recordings also in the case of Cicadomorphan songs (Figs. 4, 5). It’s noteworthy that the latter samples include an acoustic aggression behaviour as reported by Sueur & Aubin (2003) for the same species in Corse: the loud, competitive interaction between two male specimens, one of them "clicking" and the other "buzzing" in answer to the "clicks".

The male calling song (oscillogram, Figs. 4–6) is typical of *T. corsica*. It’s currently believed that the two subspecies, *T. corsica corsica* and *T. corsica farmairei* can not be separated based on their songs, that show no appreciable differences between the insular and the continental subspecies (J. Sueur pers. comm.).

The whole frequency scope spectrum analysis (Fig. 7) allows to observe that, besides the cluster of audible frequency peaks centred around 10 kHz, the sound pattern can be quite clearly made out up to around half of the spectrogram, before hitting the background noise floor observed at around -78 dB. As explained above, the intensity peak at around 71 kHz is a peculiar noise component to be ignored. To give evidence of the song’s spectral structure, figure 7 includes five brackets, C1/C5, corresponding each to a specific frequency band limited by a sharp decrease in sound pressure. Within each cluster (with the exception of C4) two main sub-clusters can be made out, with the lower frequency sub-cluster containing the highest sound pressure peaks. Components above the background noise and attributable to the singing specimen can be made out with sufficient clarity up to 56 kHz.

Although the complexity and peculiarities of the Cicadomorpha sound apparatus do not allow for a song with clearly outstanding fundamental frequencies, as those observed in Orthopteran songs in Brizio & Buzzetti (2014), it can be easily recognized how the song acoustic signature, in frequency bands if not in clearly observable high-order harmonic frequencies, is observable well above the audible range.

The time-frequency spectrogram (Fig. 8) gives further evidence of the presence of ultrasonic, structured higher-order components replicating the main audible band centered around 11 kHz.

Cicada orni Linnaeus, 1758

EVIDENCE COLLECTED. Bioacoustical evidence.

EXAMINED MATERIAL. Italy, Sardinia, Capo Pecora (Medio Campidano Province), Latitude 39.450908, Longitude 8.396298, 30 m asl, approximate nearest recording distance 15 m. Italy, Emilia Romagna, Poggio Renatico (Ferrara Province), Latitude 44.761475, Longitude 11.473074, 10 m asl, approximate nearest recording distance 20-25 m.

DISTRIBUTION.This species is distributed in all the Italian territory.

REMARKS. The ultrasound recordings took place near Capo Pecora, collecting the sound of specimens singing from the pine trees and from the highest shrubs. The following year, further recordings for comparison purposes were obtained in PoggioRenatico, in the Padan Plain of mainland Italy, from specimens singing from English Oaks, Laurel Oaks, Tree of Heaven *Ailanthus altissima* (Mill.) Swingle in an urban private park.

The unmistakeable calling song (oscillogram, Figs. 9, 10) of *C. orni*, based on repetitive echemes and well described in literature (for example by Sueur et al. (2008)) substantially differs from the more or less continuous, hissing and higher pitched emission by *T. corsica corsica*.

The frequency analysis of the whole spectral range of a single echeme (Fig. 11), shows a song whose conventional subdivision in “bands”, here proposed as an aid in the observation of the song structure, isn’t as evident as in the song of *T. corsica corsica*. Apart showing a less defined pattern, components above the background noise and attributable to the singing specimen can be clearly made out up to approximately 80 kHz. By rescaling the illustration above, one can find a substantial agreement with Figure 2C in Sueur et al. (2008), with vibration spectra displaying an higher relative amplitude around 50 kHz and an increase towards 80 kHz. As reported by Sueur et al. (2008), in the high frequency domain the tympanal membrane (TM) of the female *C. orni* is driven at its best resonance frequency at 50 kHz, a frequency domain represented by bands C4 and C5 in Fig. 11 and Table 2.

Two excerpts from *C. orni* songs Ultramic recordings were compared with frequency analyses from Sueur et al. (2008), as illustrated in Fig. 12. Although obtained in different ambient conditions, the two examined excerpts show some consistent features with the sample of *C. orni* tympanal membrane vibration spectra obtained by Sueur et al. (2008)

- two or three "humps" between 40 kHz and 50 kHz, consistent with some of the male specimens (faint blue lines)
- sharp energy increase at around 50 kHz
- three "humps" between 50 and 60 kHz, consistent with several of the female specimens (faint red lines)
- gradual energy increase towards 80 kHz

Frequencies above 80 kHz were not reported in Sueur et al. (2008)

Time-Frequency spectrogram (Fig. 13), allows to observe the synchronicity in the emission of the high-frequency and the audible frequency components of the song. Components attributable to the singing specimen can be made out with sufficient clarity up to 80 kHz.

As a novelty from an higher frequency range than that explored by Sueur et al. (2008), a faint “tail” (a frequency cluster roughly centred at 95 kHz) lasting around 300 msec was observed immediately following some of the better defined emissions (lasting around 100 msec) in the 80 kHz band. By further contrast enhancement of the time-frequency spectrogram, and by extending the spectral analysis to a lapse of time of around 300 msec, encompassing the “tail”, the presence of this further emission band can be observed in Fig. 14 and in Fig. 15, emerging

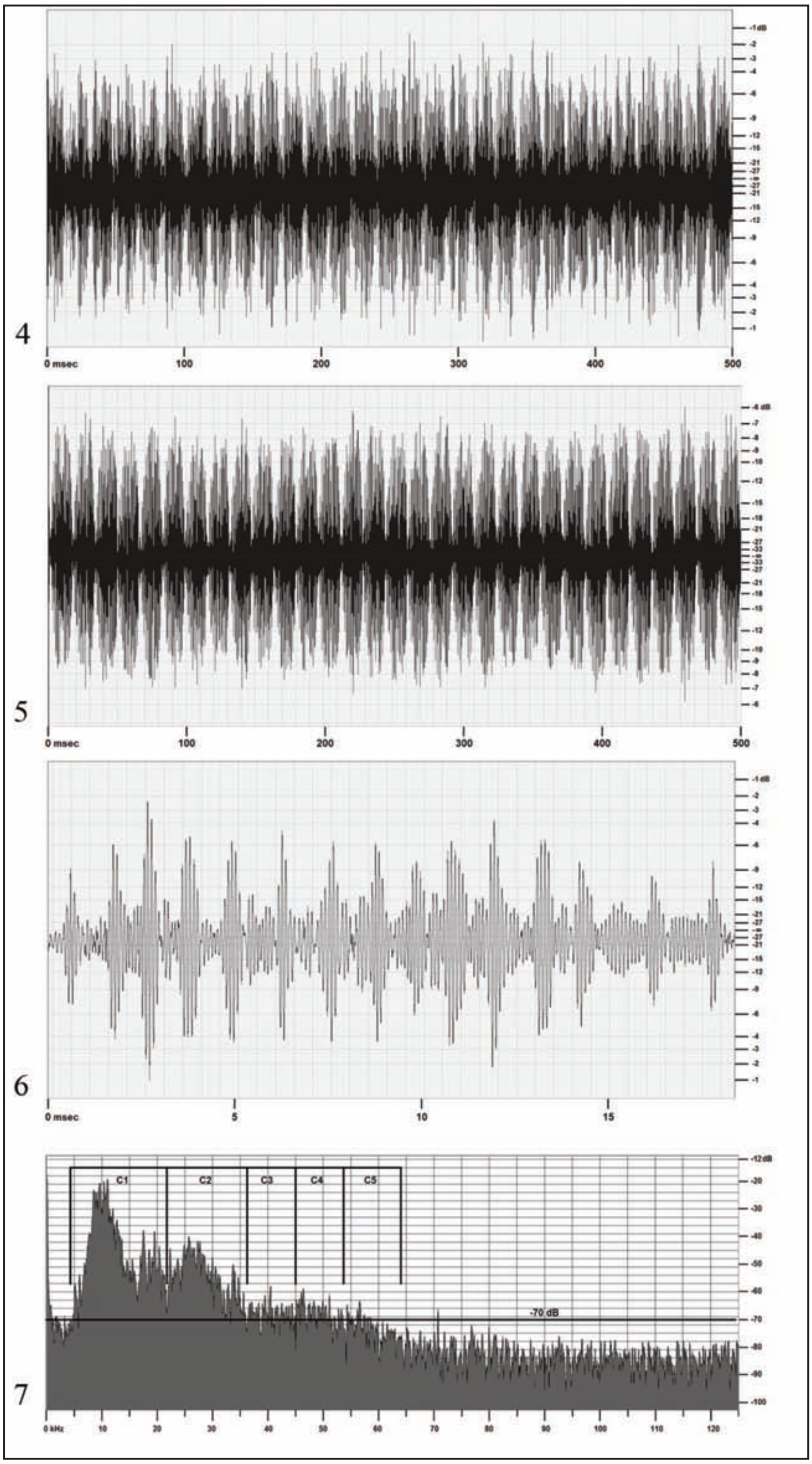


Figure 4. Song of *Tibicina corsica corsica*. Oscillogram, calling song -500 msec. Figure 5. Song of *T. corsica corsica*. Calling song -500 msec. This oscillogram from a 96 kHz recording of another specimen, obtained by a non-ultrasonic microphone based on Panasonic WM-64 capsules, is very similar to Fig. 4, and shows an overall good oscillogram consistency between Ultramic and ordinary recordings. Figure 6. Song of *T. corsica corsica*. Oscillogram, calling song: Sound unit (echeme) -19 msec. Figure 7. Song of *T. corsica corsica*. Frequency spectrum analysis of the calling song, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume window -12dB / -100dB. C1/C5: main “bands” or “frequency clusters” observed.

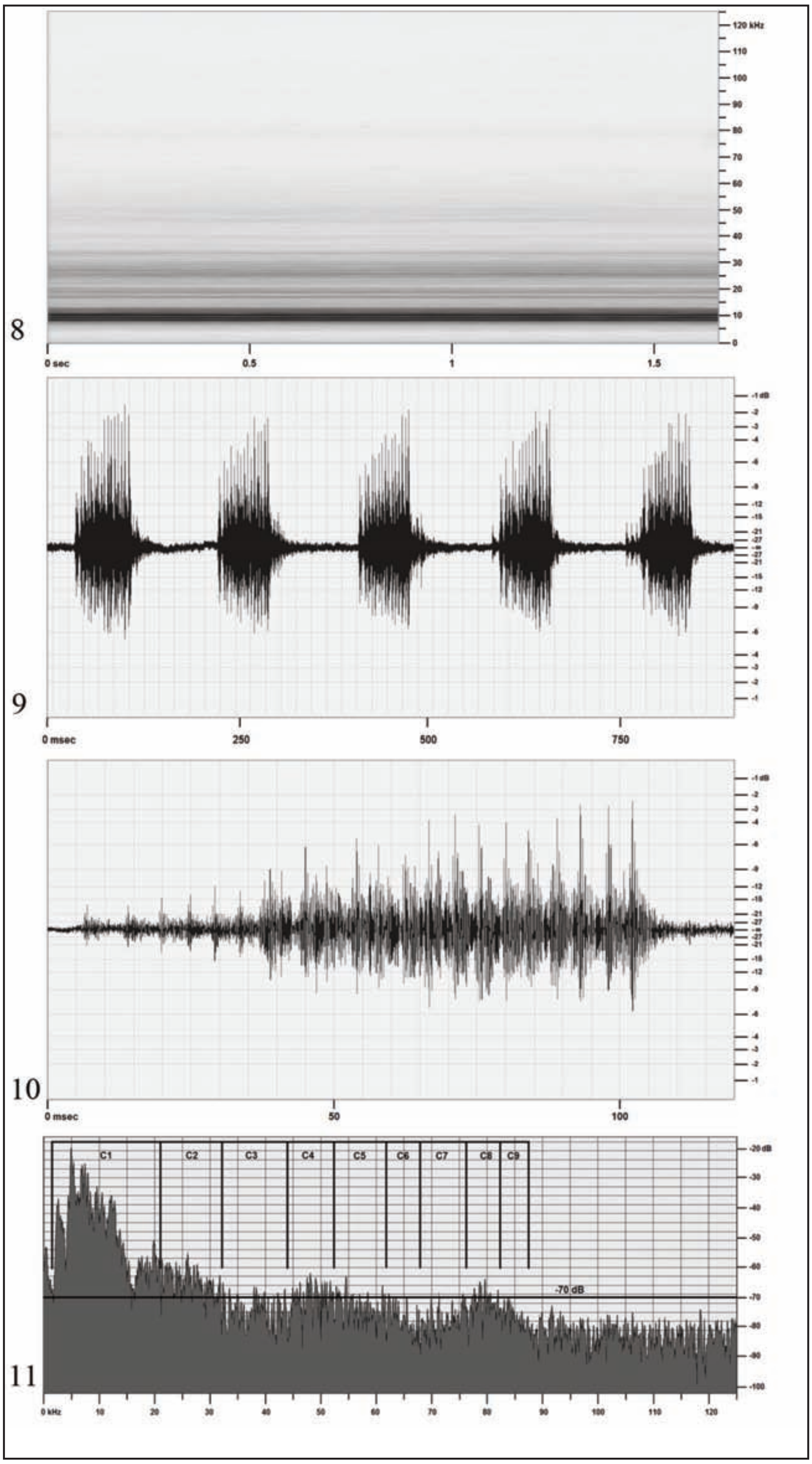


Figure 8. Song of *Tibicina corsica corsica*. Time-frequency spectrogram, 0-125kHz. The faint peak at 71 kHz is a spurious artifact from an unidentified external source. Figure 9. Song of *Cicada orni*. Oscillogram, calling song -870 msec. Figure 10. Song of *C. orni*. Oscillogram, calling song: Sound unit (echeme) -120 msec. Figure 11. Song of *C. orni*. Frequency spectrum analysis of a single soung unit, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume range below -20dB.Volume window -12dB / -100dB. C1/C9: main “bands” or “frequency clusters” observed.

Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB
C1	8483	-23.24	C1	19470	-38.24	C3	40460	-57.98
C1	9582	-20.58	C1	20320	-43.16	C3	44250	-65.95
C1	10310	-19.98	C2	22270	-44.30	C4	46380	-58.94
C1	10980	-19.18	C2	25690	-39.33	C4	51080	-60.76
C1	11960	-29.91	C2	27280	-41.60	C5	54320	-64.69
C1	12690	-33.94	C2	33690	-50.17	C5	56510	-63.45
C1	17510	-37.67	C3	39420	-61.36	C5	56430	-68.53

Table 1. Song of *Tibicina corsica corsica*. Frequency spectrum analysis of the calling song, a selection of the main observed frequency peaks above -70 dB and their sound pressures from the Ultramic 250 recording.

Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB	Band	Frequency Hz	Volume dB
C1	2563	-36.98	C1	19770	-50.64	C5	54500	-63.30
C1	4882	-19.53	C2	25930	-55.13	C5	61090	-66.48
C1	7385	-24.84	C3	37900	-66.48	C7	71280	-68.45
C1	9521	-33.42	C4	48090	-63.05	C8	78730	-65.22
C1	10490	-35.22	C4	49010	-63.78	C8	79580	-64.11

Table 2. Song of *Cicada orni*. Frequency spectrum analysis of the calling song, a selection of the main observed frequency peaks above -70 dB and their sound pressures from the Ultramic 250 recording.

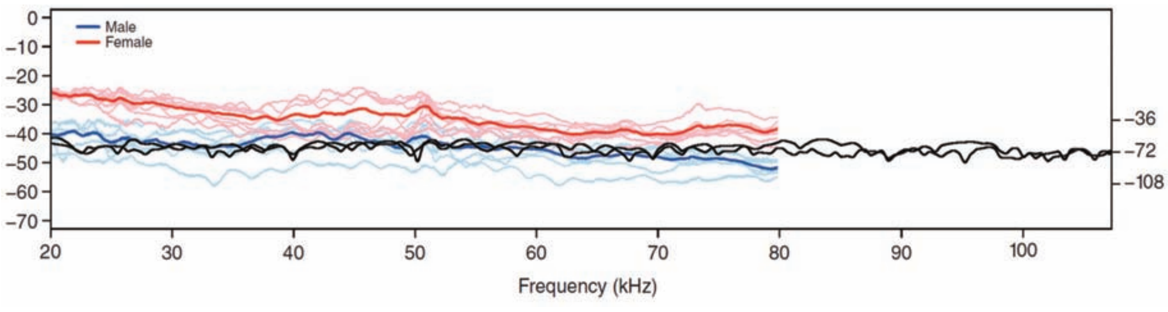


Figure 12. Song of *Cicada orni*. Two frequency analyses of 300 msec excerpts, centered at -72 dB, from *C. orni* Ultramic recordings (solid black lines) are superimposed to average *C. orni* male tympanal membrane vibration spectra (blue lines: male songs, red lines: female songs) measured in laboratory conditions. Illustration modified from Fig. 2 C from Sueur et al. (2008) - frequency range 20 kHz- 110 kHz ca.

above the limit of -70 dB and thus becoming observable in the time-frequency spectrogram.

The 80 kHz components do not appear regularly. Similarly, the 95 kHz band does not follow every echeme containing the 80 kHz band. Having not observed any of the following:

- a total decoupling of the 80 kHz and 95 kHz components from the *C. orni* echemes,
- 80 kHz and 95 kHz components in other Ultramic recordings,
- 80 kHz and 95 kHz components in Ultramic recordings from the same stations during the pauses

between *C. orni* song bouts, the author finds much more probable that those components are an integral, although occasional, part of *C. orni* song units rather than software artefacts emerging at spectrogram rendering level, or artefacts from Ultramic.

The synchronicity of the 80 kHz emission with some of the echemes, and the appearance of the highest frequency emissions here reported both in the frequency analysis mode and in time-frequency spectrograms corroborate this preliminary conclusion.

In August 2014, recordings of *C. orni* song, including the highest frequency components, were obtained in Poggio Renatico (mainland Italy, Padan Plain) for comparison purposes, in particular to investigate the high frequency "tail". Specimens were recorded from a slightly higher distance (around 20 m) than the previous year in Sardinia. The recordings showed frequent occurrences of the same pattern of irregular high frequency "tails" observed in August 2013 in Sardinia, affecting a band of about 20 kHz from around 75 kHz to around 95 kHz.

For comparison purposes, in the subsequent night and morning the acoustic/ultrasound background was recorded in the same location (Poggio Renatico) of the recordings described above, with the same settings used during the day, avoiding the lapse of time from around 9 a.m. to around 9 p.m. when *C. orni* sings. Screenshots from Adobe Audition were contrast-enhanced with the same procedure as in figures 16 and 17 for comparison purposes.

Background recordings taken at around midnight (Fig. 19) and morning recordings taken at around 8 a.m. (Fig. 20) were examined for any occurrence of the discontinuous yet well recognizable pattern observed in the 75 kHz-95 kHz band of *C. orni* recordings. The author observed that:

- none of the background ultrasound components above 70 kHz exceeded the -70 dB threshold
- the 70 kHz-100 kHz band from the background recordings doesn't bear any resemblance to the same band in *C. orni* recordings. At the same time, *C. orni* recordings seem unaffected by the features appearing in the background recordings.

Background night recordings displayed Chiropteran echolocation calls and Orthopteran songs, with singing species including *Eumodicogryllus burdigalensis burdigalensis* (Latreille, 1804), *Eupholidoptera schmidti* (Fieber, 1861), *Oecanthus pellucens* (Scopoli,1763). Ultrasounds from passing bats can be made out at around 30 kHz, while the regular pattern of Orthopteran songs can be made out under 30kHz. Frequencies around 68 kHz and 98 kHz display feeble regular pulses of different duration whose probably anthropogenic origin was not investigated.

The ultrasound background above 70 kHz recorded in the morning resembled quite closely the night recording from the same location, with a persistence of the feeble pulses at around 68 kHz and 98 kHz. Their regularity in the 8 p.m.-8 a.m. period may hint at a non-biological source.

Surely, a more detailed investigation beyond the scope of this paper may corroborate or disprove the author's findings.

CONCLUSIONS

The songs by two cicadas from Sardinia have been recorded in the field, by a low-cost USB microphone capable of generating very wide band (0 to 125 kHz) monophonic recordings, including both audible and inaudible frequencies. This device, Ultramic 250, by generating results consistent with other recording methods and by providing useful information about the high-frequency components above 20 kHz and up to 125 kHz, proved as useful for the investigation of Cicadomorphan songs, as it proved to be in the study of Orthopteran songs.

The song by *T. corsica corsica* showed harmonic components (bands) up to 56 kHz, while the song by *C. orni* seems to exceed the limit of 80 kHz previously explored in literature, and may include frequencies in the 100 kHz range.

Getting a full grasp of the intraspecific and interspecific significance of the ultrasound components is beyond the scope of this contribution: it is reasonable to suppose that the species whose song is here described may have a sound generating and receiving capability even in ranges above those previously reported in literature. Questions that can be addressed include a possible role of ultrasound components in the evaluation of song direction and distance by conspecifics: a sound source may be considered omnidirectional when it emits wavelengths longer than its biggest linear dimension, while directivity is inversely proportional to

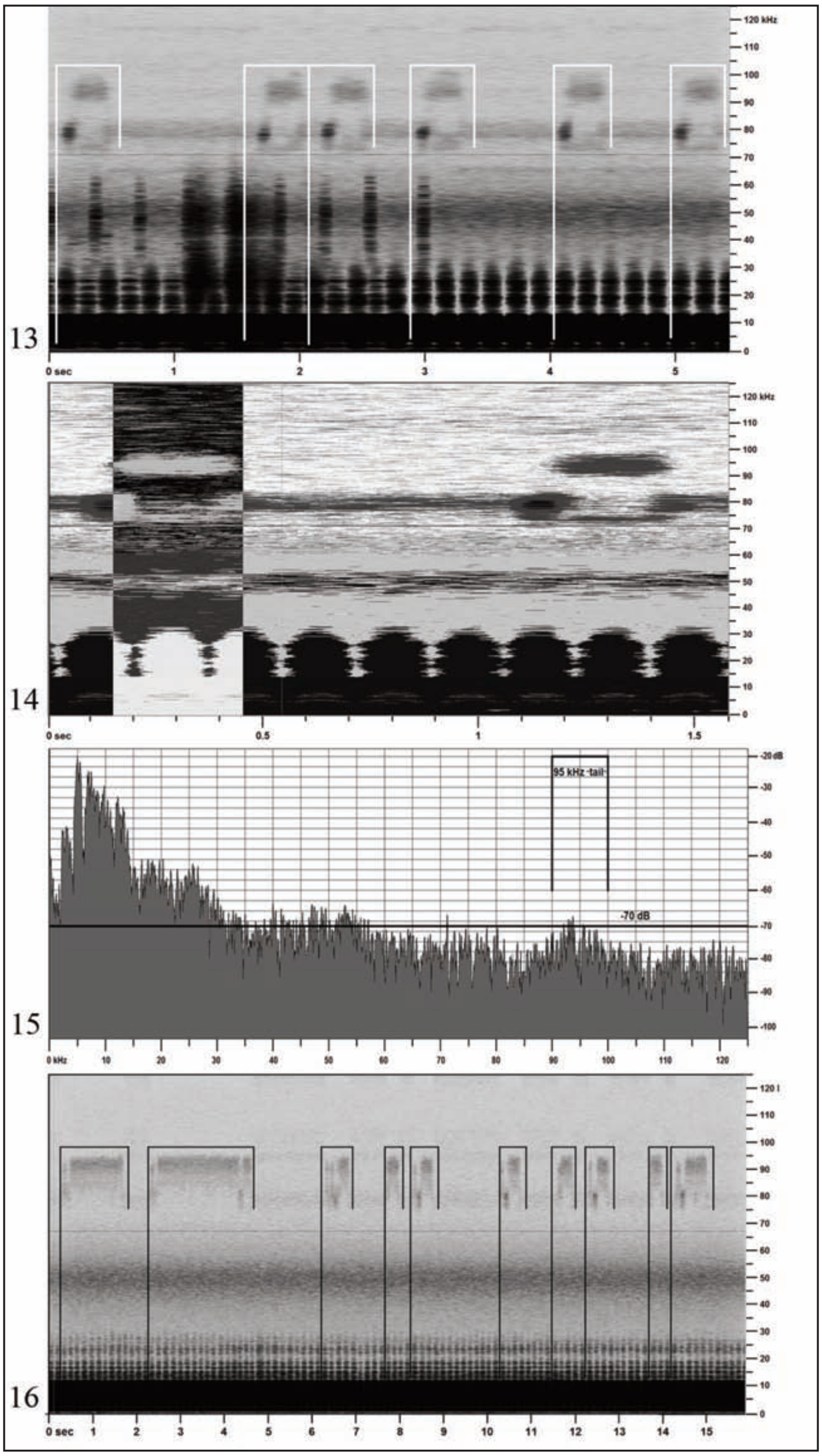
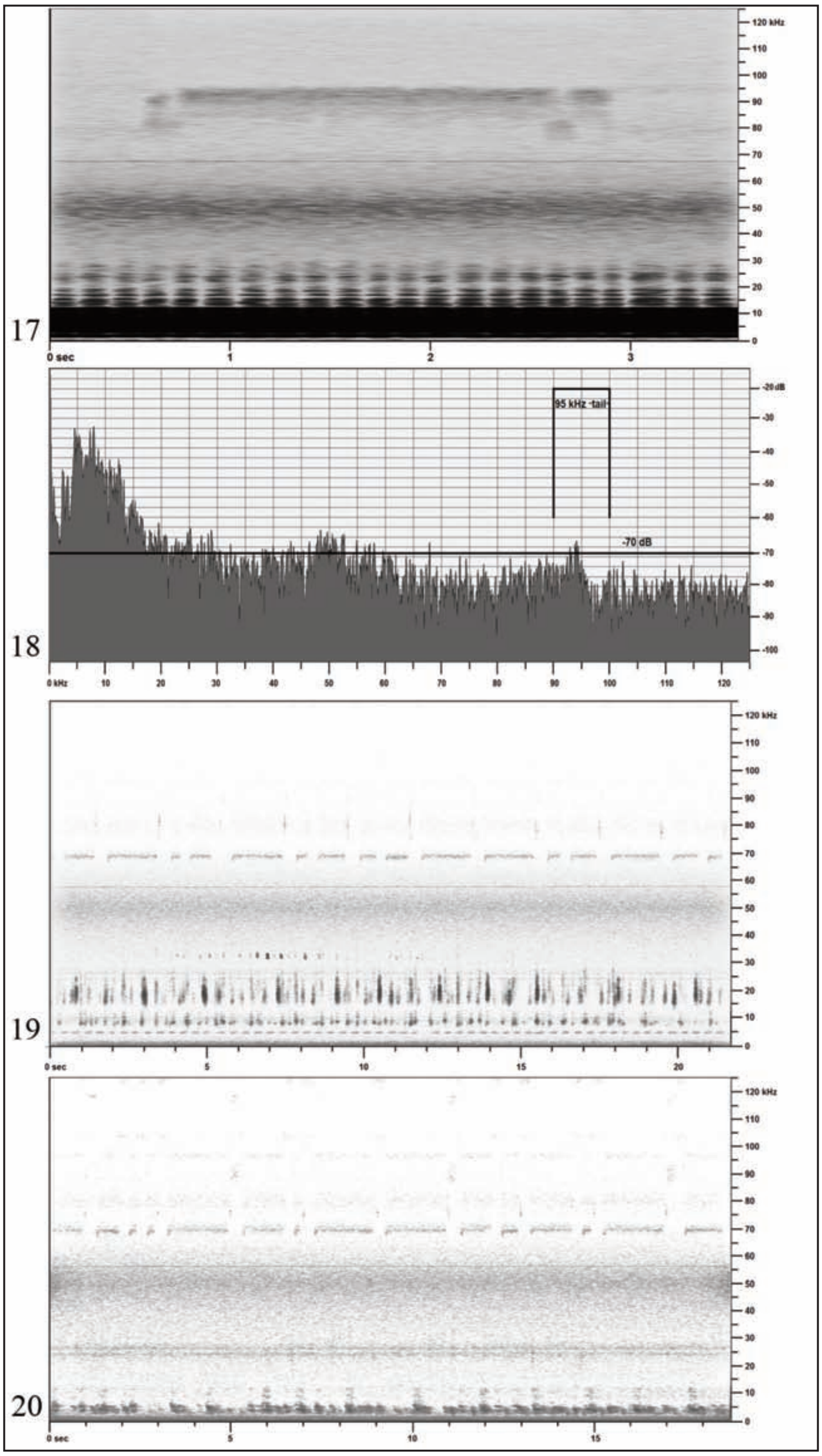


Figure 13. Song of *Cicada orni*. Enhanced contrast picture of a time-frequency spectrogram, 0-125kHz. White lines give evidence to the synchronicity of audible and inaudible spectral components, up to the frequency cluster centered at around 79 kHz and including a very faint 300 msec “tail” in the 95 kHz range. Figures 14-15. Enhanced contrast spectrogram and frequency spectrum analysis of 300 msec including the 95 kHz “tail” band, Blackmann-Harris window type, FFT size 4096 bytes, 0-125kHz. Volume range below -20 dB. Volume window -19 dB / -102dB. Figure 16. Song of *C. orni*, comparison specimen from Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. Black lines border the frequency cluster centered at around 79 kHz and including a very faint 300 msec “tail” in the 95 kHz range.



Figures 17-18. Song of *Cicada orni* from Padan Plain. Enhanced contrast spectrogram and frequency spectrum analysis of 1800 msec including the 95 kHz “tail” band, Blackmann-Harris window type, FFT size 4096 bytes, 0-125 kHz. Volume range below -20 dB. Volume window -15dB/-102 dB. Figure 19. Ultrasound background recording taken at 11:55 p.m. in the night following the recordings in Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. See text for comments. Figure 20. Ultrasound background recording taken at 7:55 a.m. in the morning following the recordings in Poggio Renatico, Padan Plain. Enhanced contrast picture of a time-frequency spectrogram, 0-125 kHz. See text for comments.

wavelength. As reported for example by Miller (2000, 2002) in the case of Killer Whales *Orcinus orca* Linnaeus, 1758 (Mammalia Cetacea), as well as by Jakobsen et al. (2013) for echolocating bats, for a constant energy and emitter size, an increase in frequency, that is decrease in wavelengths, focuses the energy in a beam that is narrower (thus, more directional) but longer, which at short distances counteracts the decrease in range due to increased atmospheric attenuation at higher frequencies. Unfortunately, field recording condition and uncontrollable specimen position in the wild did not allow to draw any conclusion about the orientation of the singing specimen relative to the microphone axis, neither to measure the different relevance of ultrasound components at different angles between the singing specimen and the microphone.

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