Calling songs of certain orthopteran species (Insecta, Orthoptera) in southern Portugal

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Abstract

Calling songs of certain orthopteran species (Insecta, Orthoptera) in southern Portugal.— The calling songs produced by males of the Orthoptera occurring at the field station "Herdade da Ribeira Abaixo" (Centre for Environmental Biology), in Grândola (southern Portugal), are described. The songs were recorded in the field with a portable professional DAT recorder and were analysed in the form of oscillograms and sonagrams. Except for the interesting *Gryllotalpa vineae* Bennet–Clark, these are the 12 first descriptions of the acoustic parameters and behaviour of the Portuguese populations of the 13 species occurring at the field station and which belong to the following genera: *Conocephalus* Thunberg, *Tettigonia* Linnaeus, *Platycleis* Fieber, *Thyreonotus* Serville and *Uromenus* Bolívar (Tettigoniidae), *Gryllus* Linnaeus, *Nemobius* Serville and *Oecanthus* Serville (Gryllidae), *Gryllotalpa* Latreille (Gryllotalpidae), and *Omocestus* Bolívar and *Euchorthippus* Tarbinskii (Acrididae). All species, including pairs and closely related groups, can be readily separated by temporal and frequency parameters of the calling songs through oscillogram and sonagram analyses. *Platycleis sabulosa* Azam is a new record for Portugal.

Key words: Orthoptera, Calling songs, Oscillograms, Sonagrams, New record, Portugal.

Resumen

Cantos de llamada en algunas especies de ortópteros (Insecta, Orthoptera) del sur de Portugal.— Se describen los cantos de llamada producidos por machos de ortópteros en el centro de observación "Herdade da Ribeira Abaixo" (Centro de Biología Ambiental), de Grândola (sur de Portugal). Los cantos fueron registrados mediante una grabadora portátil profesional DAT, analizándose en forma de oscilogramas y sonogramas. A excepción del interesante *Gryllotalpa vineae* Bennet–Clark, se dan las 12 primeras descripciones de los parámetros acústicos y de comportamiento de las poblaciones portuguesas de las 13 especies presentes en el centro de observación y que pertenecen a los siguientes géneros: *Conocephalus* Thunberg, *Tettigonia* Linnaeus, *Platycleis* Fieber, *Thyreonotus* Serville y *Uromenus* Bolívar (Tettigoniidae), *Gryllus* Linnaeus, *Nemobius* Serville y *Oecanthus* Serville (Gryllidae), *Gryllotalpa* Latreille (Gryllotalpidae), *Omocestus* Bolívar y *Euchorthippus* Tarbinskii (Acrididae). Todas las especies, incluidas parejas y grupos de especies muy próximas, pueden ser fácilmente identificadas a través del análisis de sus oscilogramas y sonogramas. El registro de *Platycleis sabulosa* es nuevo en Portugal.

Palabras clave: Orthoptera, Cantos de llamada, Oscilogramas, Sonogramas, Nuevo registro, Portugal.

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Introduction

Airborne vibrations are used for communication purposes by many insects, such as the majority of Orthoptera which use these signals as the most widespread method of intraspecific communication (ALEXANDER, 1968; OTTE, 1977; ELSNER, 1983; EWING, 1984; RAGGE & REYNOLDS, 1998).

Acoustic signals in Orthoptera are produced through stridulation, a process whereby vibration or sound results from the friction of one body structure against another. This may be achieved by two main methods: a tegminal mechanism, in which the sound is mainly produced during the closing stroke of the tegmina (suborder Ensifera such as Tettigoniidae, Gryllidae and Gryllotalpidae); or a femoro–tegminal mechanism, where sounds may be produced on both the up and down strokes of both hind femora against the tegmina (suborder Caelifera such as Acrididae) (e. g., RAGGE & REYNOLDS, 1998; CHAPMAN, 2000). In general, each species can produce different song patterns depending upon behavioural context (DUMORTIER, 1963; HASKELL, 1974).

In the present study only the most commonly produced sound, the "calling song", is described. Typically this acoustic signal is produced by males in order to attract conspecific females. In the Gryllidae and most Tettigoniidae the females are silent and if receptive they are induced to perform phonotaxis towards the singing conspecific male, so that individuals are brought together for mating. In other cases, both sexes may walk towards each other until visual contact is established (RAGGE & REYNOLDS, 1998). Thus, the calling song functions as a premating isolation mechanism and its structure is an important component of the specific mate recognition system (PERDECK, 1957; PATERSON, 1985). Therefore, the analysis of the calling songs may provide important taxonomic information at a specific level, namely for deciding on the status of allopatric populations showing small morphological differences or in cases of sibling species, i.e. species which have diverged without showing clear–cut external morphological differences (CLARIDGE, 1985; RAGGE & REYNOLDS, 1998).

Calling songs are species specific and since they provide the basis for a mate recognition system they are a particularly reliable indication of the species limits. RAGGE & REYNOLDS´s (1998) comprehensive account of the songs of European orthopterans, for example, puts emphasis on the taxonomy indicated by the song, for which the authors proposed the term phonotaxonomy.

Despite some previous knowledge on the acoustic behaviour of some Portuguese insects such as leafhoppers and cicadas (e.g., QUARTAU et al., 1992; QUARTAU & REBELO, 1994; QUARTAU, 1995; QUARTAU & BOULARD, 1995; QUARTAU et al., 1999c), the Orthoptera have been a neglected group in this respect. The present study gives the first descriptions of the calling songs of Portuguese populations of certain species of Orthoptera occurring in southern Portugal, *Platycleis sabulosa* Azam being a new record for Portugal. It represents part of a larger project covering the faunistics of the Homoptera and Orthoptera (Auchenorrhyncha) occurring at the field station of the Centre for Environmental Biology, in the area of Grândola (Alentejo) (QUARTAU et al., 1999a, 1999b).

Material and methods

Sound recordings were made at the field station of the Centre for Environmental Biology "Herdade da Ribeira Abaixo" near Grândola, in Alentejo (southern Portugal) from June to October of 1997 and during March of 1998.

The acoustic recordings were made in the field using digital techniques in the sonic range between 50 Hz and 18 kHz with a SONY DAT recorder TCD-D10 Pro II (tape speed: 0.85 cm/s; unidirectional microphone SONY C76). Some of the recordings were also made through a Report Monitor UHER 4200 (tape speed: mostly 19 cm/s, but also 9.5 cm/s; dynamic microphone AKG D202). The ambient air temperature at the time of the recording was always taken and is referred to in the song descriptions. Recordings and collected specimens are kept in the Department of Zoology and Anthropology with one of the authors (J. A. Quartau).

Sound recordings were analysed at the Department of Zoology and Anthropology, in Lisbon, using the PC software Cool Edit™ V96 and Avisoft–SAS Lab Light 97. The songs were visualized as oscillograms with 1 min., 10 s and 1 s and, where necessary, other time expansions. Moreover, for a more thorough description of the calling songs, sonagrams were also produced.

The terminology as well as its interpretation in connection with the leg– or wing–movements of the singer (i.e., the functioning of the stridulatory apparatus) follow RAGGE & REYNOLDS (1998): (i) calling song, the song produced by an isolated male; (ii) syllable, the sound produced by the opening stroke followed by the closing stroke of the tegmina (Ensifera) or the upstroke followed by the downstroke of the hind femur (Gomphocerinae grasshoppers); (iii) some Tettigoniidae produce two contrasting kinds of syllable, the longer ones are termed macrosyllables and the shorter ones, which usually last less than 10 ms, are the microsyllables; (iv) in Gomphocerinae grasshoppers there are momentary breaks in the sound during the louder part of the syllable, of at least 1.25 ms duration, which are called gaps; (v) diplosyllable, a syllable in which sound is generated by both directional movements of the stridulatory apparatus; (vi) hemisyllable, the sound produced by one unidirectional movement of the elytra or hind femora; (vii) echeme, a first–order assemblage of syllables; (viii) echeme–sequence, a first–order assemblage of echemes; and (ix) carrier wave, the fundamental wave of a resonant song, i.e., a song with an almost pure dominant frequency.

Whenever available, the duration of echemes, syllables and gaps were based on at least ten measurements involving one or two males.

Results

Fieldwork provided a total of 21 acoustic recordings of the male calling song from 13 distinct species: six bush–crickets, four crickets, one mole–cricket and two grasshoppers. Specimens were collected on low grass, on top of shrubs and on trees, and on the riparian vegetation of the field station.

Song descriptions

Conocephalus discolor Thunberg, 1815 (Tettigoniidae, Conocephalinae)

This species was always found near the stream of the field station, on *Scirpus holoshoenus* L., and called during the day–time and at sunset on the warm days in August. The song sounded like a quiet or faint sizzling, audible at a distance of 4 to 5 m. The calling song, recorded at 28°C, consisted of trisyllabic echemes (figs. 1A–1F). The syllables consisted of short opening hemisyllables, followed by longer closing hemisyllables (fig. 1F); the first diplosyllable lasted about 16 ms, was followed by a gap of about 2 ms, and then the second one lasted about 15 ms. The third diplosyllable lasted about 25 ms and followed the

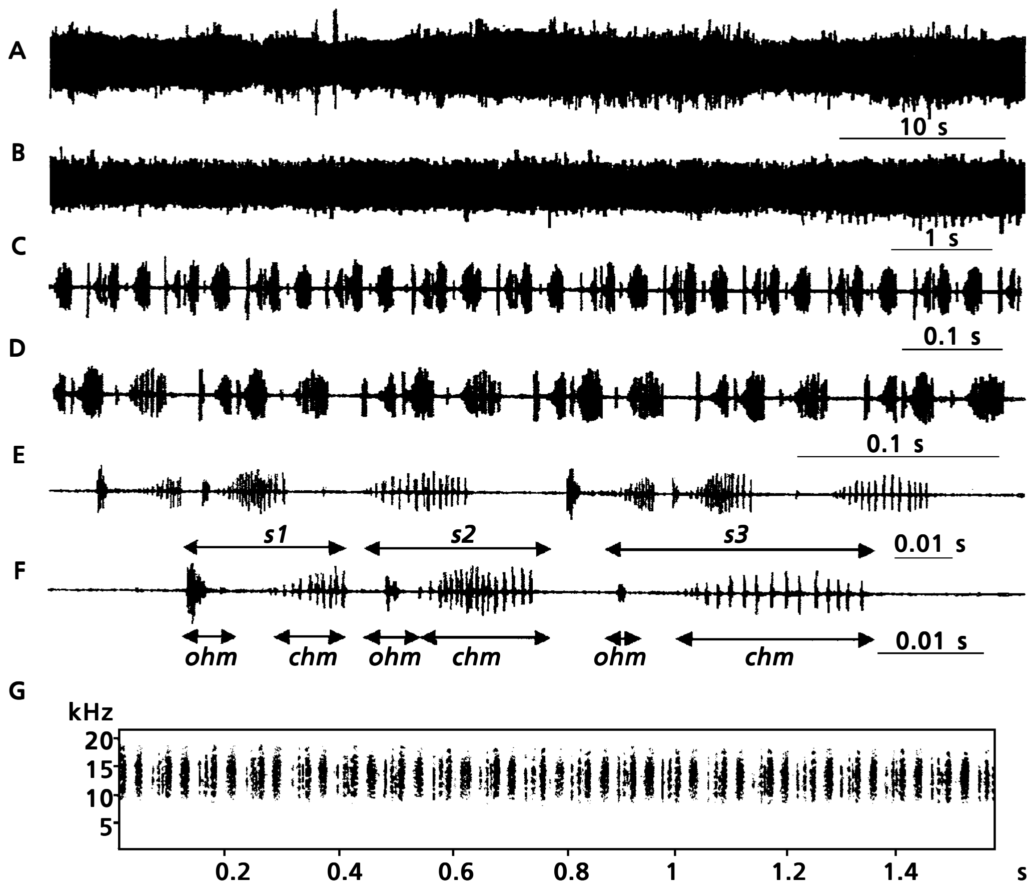

Fig. 1. Oscillograms and sonagram of the calling song of a male of *Conocephalus discolor* at 28°C: A. 1 min.; B. 10 s; C. 1 s; D. 0.5 s; E. 170 ms; F. One echeme; *s1.* First syllable; *s2.* Second syllable; *s3.* Third syllable; *ohm.* Opening hemisyllable; *chm.* Closing hemisyllable; G. Sonagram, showing the audible frequencies of the calling song ranging from about 8 to 19 kHz.

Fig. 1. Oscilogramas y sonograma del canto de llamada del macho de Conocephalus discolor *a 28°C: A. 1 min.; B. 10 s; C. 1 s; D. 0,5 s; E. 170 ms; F. Un "echeme"; s1. Primera sílaba; s2. Segunda sílaba; s3. Tercera sílaba; ohm. Hemisílaba inicial; chm. Hemisílaba final; G. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 8 y 19 kHz.*

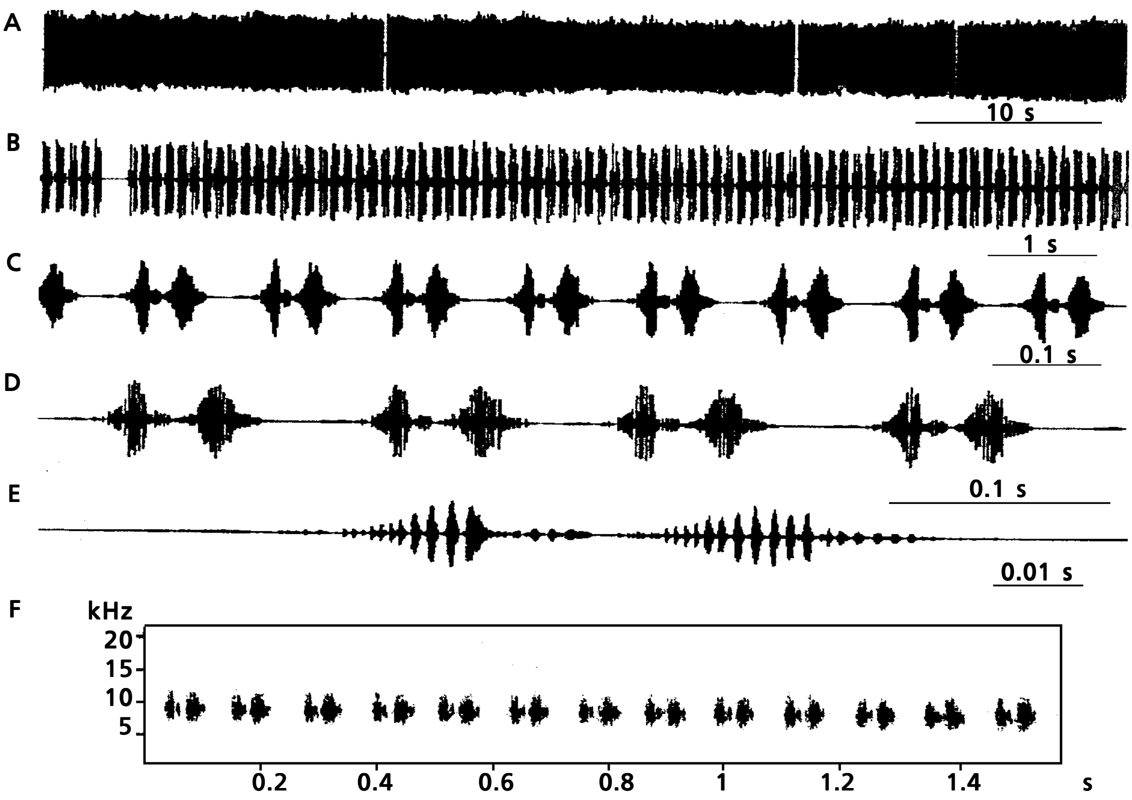

Fig. 2. Oscillograms and sonagram of the calling song of a male of *Tettigonia viridissima* at 20°C: A. 1 min.; B. 10 s; C. 1 s; D. 0.5 s; E. 121 ms; F. Sonagram, showing the audible frequencies of the calling song ranging from about 6 to 13 kHz.

Fig. 2. Oscilogramas y sonograma del canto de llamada del macho de Tettigonia viridissima *a 20°C: A. 1 min.; B. 10 s; C. 1 s; D. 0,5 s; E. 121 ms; F. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 6 y 13 kHz.*

second after a gap of about 6 ms. The first opening hemisyllable was very prominent, contrasting with the third one which can be quite faint (figs. 1A–1F). The audible frequencies of the calling song ranged from about 8 to 19 kHz (fig. 1G).

Tettigonia viridissima (Linnaeus, 1758) (Tettigoniidae, Tettigoniinae)

This loud calling song was heard mainly in the end of June and the beginning of July. It was produced by males in the late afternoon and at night on top of shrubs and trees. The calling song, recorded at 20°C, consisted of echeme-sequences interrupted at irregular intervals by pauses shorter than one second (figs. 2A–2B). The echemes were disyllabic (with two closing hemisyllables), lasting 80–90 ms, with gaps of 20–40 ms between them and were produced at the repetition rate of about 8/s (figs. 2C–2D). The first closing hemisyllable, with a duration of about 30 ms, was slightly shorter than the second, which lasted about 40 ms (fig. 2E).The dominant audible frequencies of the calling song ranged from about 6 to 13 kHz (fig. 2F).

Platycleis sabulosa Azam, 1901 (Tettigoniidae, Decticinae)

This species was recorded in the afternoon and after dark, during August on low grasses and small shrubs. The calling song, recording at 25°C, consisted of long sequences of echemes repeated regularly at the rate of about two per second (figs. 3A–3B). Each echeme lasted 246–318 ms and consisted of five to six syllables repeated at the rate of about 18/s (figs. 3C–3D). The syllables present on the oscillogram are closing hemisyllables, lasting 40–50 ms each, with the opening hemisyllables absent (Ragge & Reynolds, 1998). The closing hemisyllables usually increased slightly in amplitude throughout the

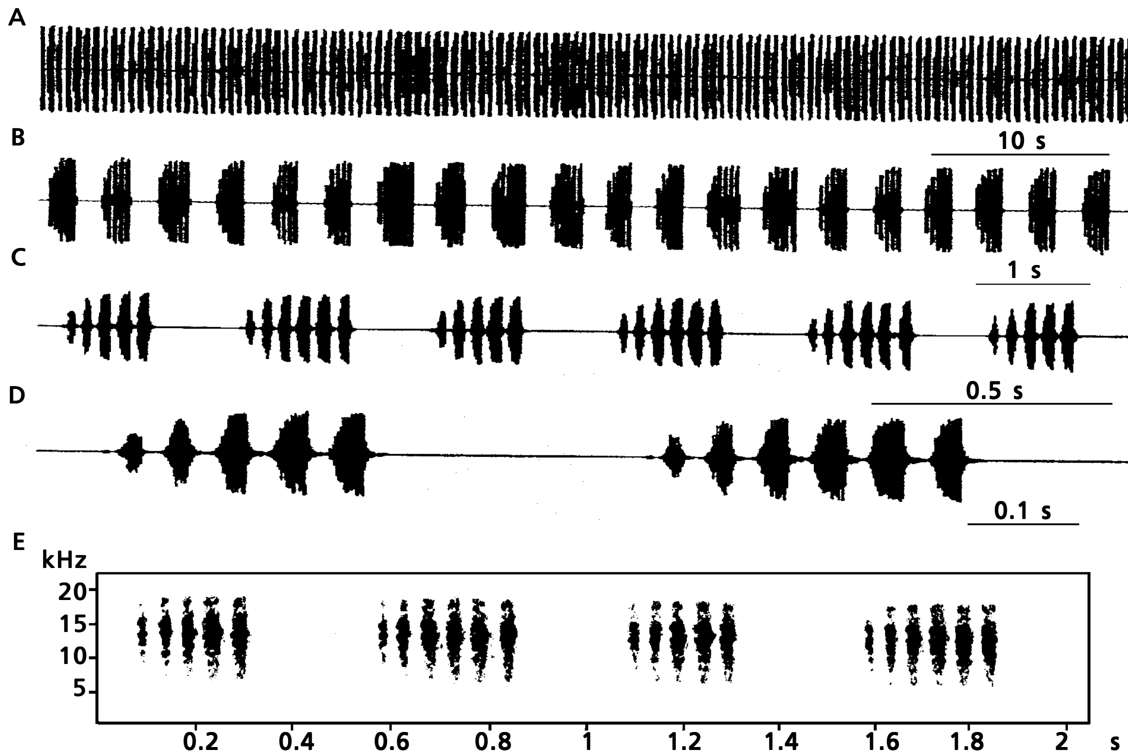

Fig. 3. Oscillograms and sonagram of the calling song of a male of *Platycleis sabulosa* at 25°C: A. 1 min.; B. 10 s; C. 2.3 s; D. 1 s; E. Sonagram, showing the audible frequencies of the calling song ranging from about 6 to 19 kHz.

Fig. 3. Oscilogramas y sonograma del canto de llamada del macho de Platycleis sabulosa *a 25°C: A. 1 min.; B. 10 s; C. 2,3 s; D. 1 s; E. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 6 y 19 kHz.*

echeme (figs. 3A–3D), appearing slightly longer than those given by RAGGE & REYNOLDS (1998). The audible frequencies of the calling song ranged from about 6 to 19 kHz (fig. 3E).This is a new record for Portugal.

Platycleis affinis Fieber, 1853 (Tettigoniidae, Decticinae)

This species was found on low grass, in the evening and early at night in August. The calling song, recorded at 28°C, consisted of a typical mixture of short echemes (figs. 4C–4F), lasting less than one second and usually composed of three to four macrosyllables, and longer echemes (figs. 4C–4D) lasting from four to eight seconds and composed of 33–53 macrosyllables; these latter, therefore, slightly longer than those given by RAGGE & REYNOLDS (1998). Each echeme usually ends with a series of 7–10 microsyllables. The echemes are often grouped into two to five short ones followed by a long one (fig. 4A–4B). Macrosyllables are repeated at the rate of about eight per second and microsyllables at about 21/s. Similarly to *P. sabulosa*, the audible frequencies of the calling song ranged from about 7 to 19 kHz (fig. 4G).

Platycleis intermedia (Serville, 1838) (Tettigoniidae, Decticinae)

This bush–cricket called on low grasses and on small shrubs mostly in the late evening and at night in August and September. The calling song, recorded at 28°C, consisted of long sequences of disyllabic echemes, consisting of two closing hemisyllables, and repeated at the rate of about three per second (figs. 5A–5B); the duration of each echeme varied between 150 and 160 ms and the gap between consecutive echemes varied between 160 and 180 ms. The second closing hemisyllable of each pair was slightly longer and louder than the first (figs. 5C–5D). As with the two previous species, the audible frequencies of the calling song ranged from about 6 to 19 kHz (fig. 5E).

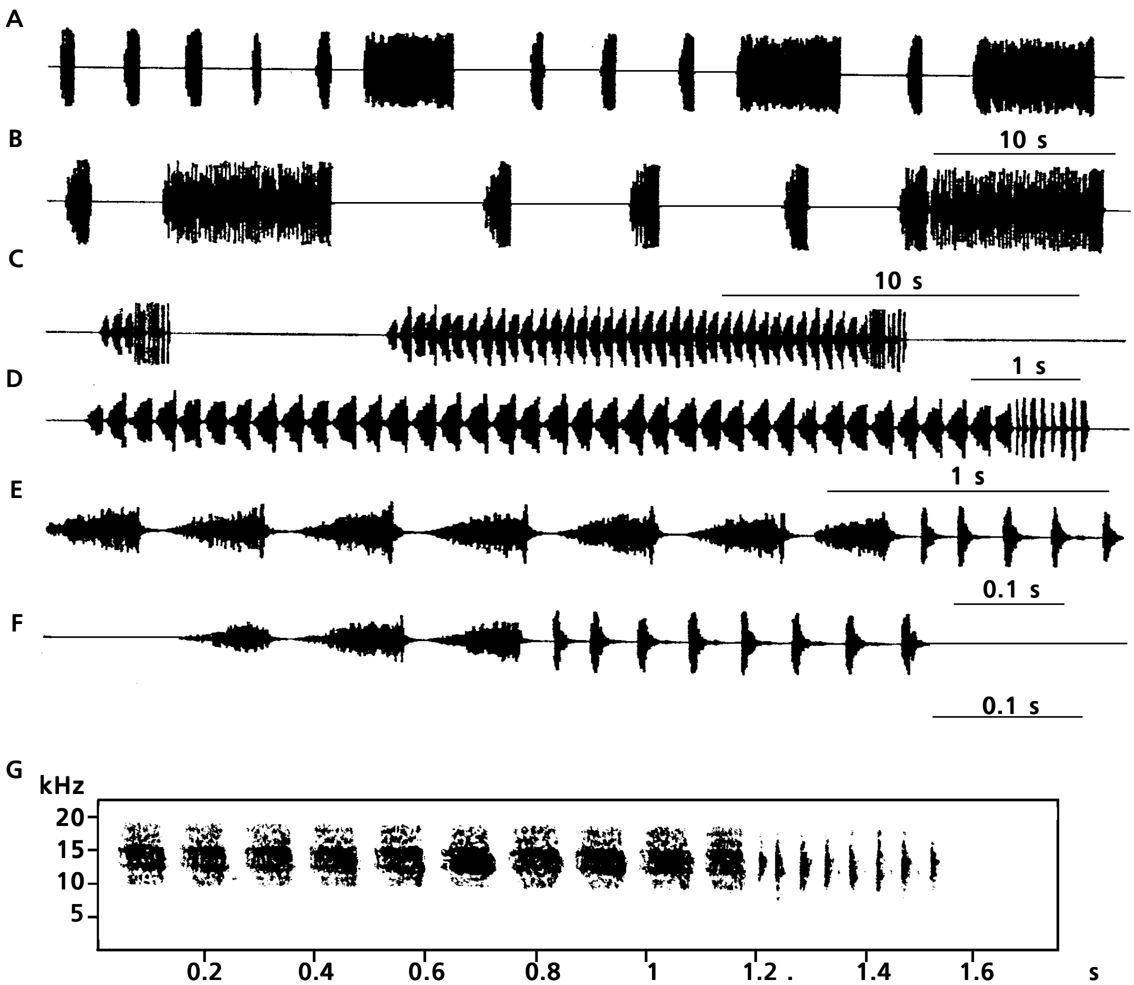

Fig. 4. Oscillograms and sonagram of the calling song of a male of *Platycleis affinis* at 28°C: A. 1 min.; B. 30 s; C. 10 s; D. 3.9 s; E. 1 s; F. 0.7 s; G. Sonagram, showing the audible frequencies of the calling song ranging from about 7 to 19 kHz.

Fig. 4. Oscilogramas y sonograma del canto de llamada del macho de Platycleis affinis *a 28°C: A. 1 min.; B. 30 s; C. 10 s; D. 3,9 s; E. 1 s; F. 0,7 s; G. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 7 y 19 kHz.*

Thyreonotus bidens Bolívar, 1887 (Tettigoniidae, Decticinae)

This species is camouflaged by a colouration closely matching the trunk and branches of the *Quercus* spp. trees where it was found. The song was produced late afternoon and at night in September and October. The calling song, recorded at 28°C, consisted of 1–28 single syllables repeated at the rate of about two per second (figs. 6A–6F). Each syllable varied in duration between 195 ms and 320 ms and consisted of a very small opening hemisyllable and a much longer closing hemisyllable, most of the sound being produced in the closing hemisyllable (figs. 6B–6E). The gaps between syllables ranged from 278 ms to 822 ms. The audible frequencies of the calling song ranged from about 7 to 19 kHz (fig. 6F).

Gryllus campestris Linnaeus, 1758 (Gryllidae, Gryllinae)

This cricket can be heard at the entrance to a burrow at any time of the day or night mostly from May to July. The calling song, recorded at 20°C, consisted of long and loud echeme–sequences, produced at the rate of about three per second (figs. 7B–7C). Each echeme varied in duration between 104 ms and 113 ms and was

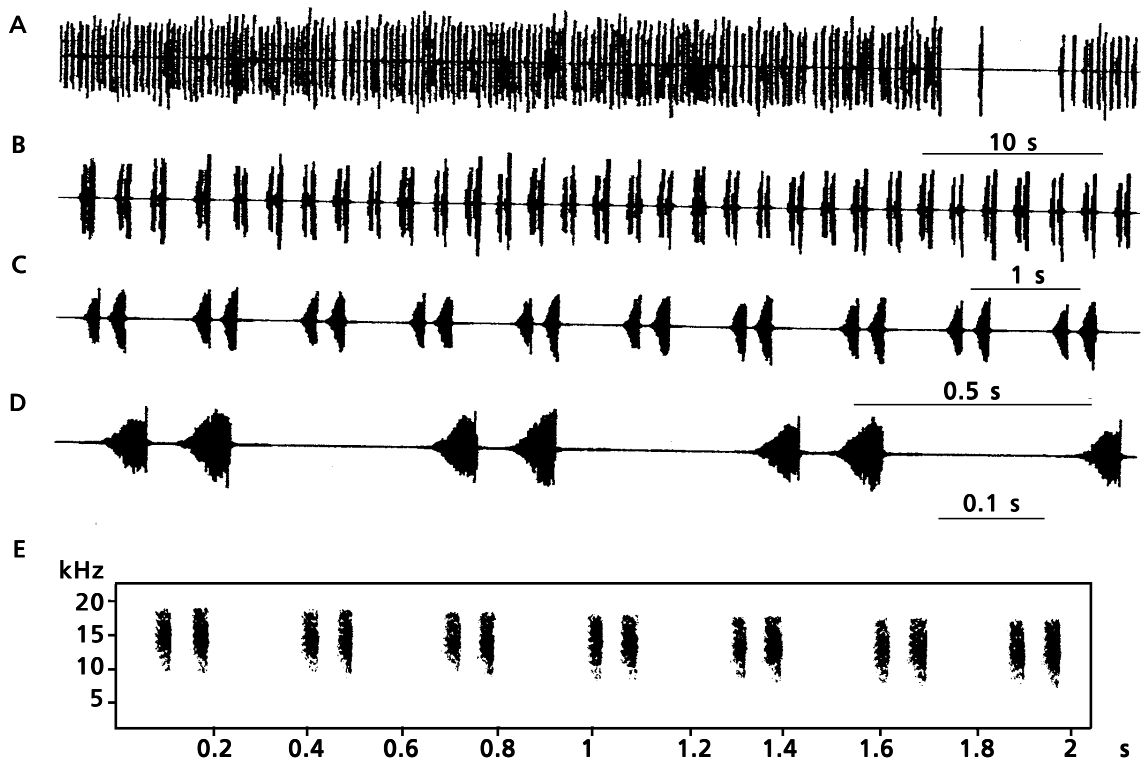

Fig. 5. Oscillograms and sonagram of the calling song of a male of *Platycleis intermedia* at 28°C: A. 1 min.; B. 10 s; C. 2.3 s; D. 1 s; E. Sonagram, showing the audible frequencies of the calling song ranging from about 6 to 19 kHz.

Fig. 5. Oscilogramas y sonograma del canto de llamada del macho de Platycleis intermedia *a 28°C: A. 1 min.; B. 10 s; C. 2,3 s; D. 1 s; E. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 6 y 19 kHz.*

composed of four closing hemisyllables at the repetition rate, within an echeme, of about 24/s. The gaps between echemes ranged from 176 ms to 745 ms. The first hemisyllable was in general quieter than the remaining three and in general a *crescendo* continued throughout the echeme (figs. 7C–7D) as referred to by RAGGE & REYNOLDS (1998). The frequency of the carrier wave was about 4 kHz (fig. 7E).

Gryllus bimaculatus De Geer, 1773 (Gryllidae, Gryllinae)

Like the previous species, this cricket called from the entrance to a burrow during the afternoon and mainly during the night from August until October. The calling song, recorded at 27°C, was very similar to that of *G. campestris* (fig. 8): it consisted of long sequences of tetrasyllabic echemes of closing hemisyllables, repeated within each echeme at the rate of about 24/s. The echeme repetition rate was similar to that in the previous cricket with about three per second but, in contrast with *G. campestris*, all the hemisyllables were similar in duration and amplitude (figs. 8C–8D). Each echeme lasted from 113 ms to 132 ms, appearing therefore slightly longer than in *G. campestris*. The gaps between echemes varied from 176 ms to 235 ms. The frequency of the carrier wave was about 4.5 kHz, therefore slightly higher than in *G. campestris* (fig. 8E).

Nemobius sylvestris (Bosc, 1792) (Gryllidae, Nemobiinae)

This small cricket called any time of the day or night during September and October, and was found in moist places in the ground under leaves, *e.g.* the bed and shores of dried temporary brooks of the field station. The presumable calling song, recorded at 29°C, consisted of sequences of long

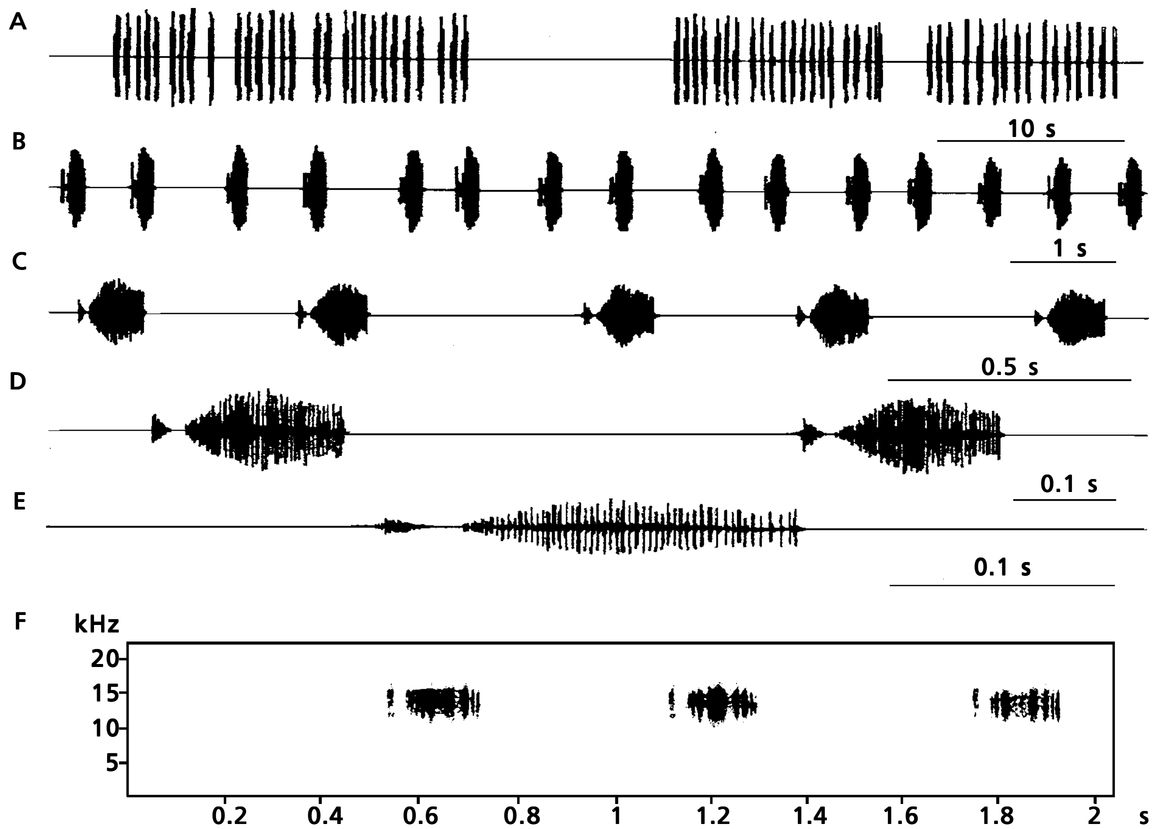

Fig. 6. Oscillograms and sonagram of the calling song of a male of *Thyreonotus bidens* at 28ºC: A. 1 min.; B. 10 s; C. 2.3 s; D. 1 s; E. 0.5 s; F. Sonagram, showing the audible frequencies of the calling song ranging from about 7 to 19 kHz.

Fig. 6. Oscilogramas y sonograma del canto de llamada del macho de Thyreonotus bidens *a 28ºC: A. 1 min.; B. 10 s; C. 2,3 s; D. 1 s; E. 0,5 s; F. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 7 y 19 kHz.*

echemes repeated at the rate of about 0.5/s (figs. 9A–9B). The duration of each echeme depended on the number of syllables, which were between 12 and 62 (fig. 9C), therefore considerably longer than those described by RAGGE & REYNOLDS (1998). It is possible that this atypical sound might represent instead a courtship sound. The syllables were repeated at the rate of about 32/s, lasting about 9 ms each and with a gap of 15 to 20 ms between them. The first 8–12 syllables showed an increase in amplitude (figs. 9C–9D). The frequency of the carrier wave was about 3.8 kHz (fig. 9E).

Oecanthus pellucens (Scopoli, 1763) (Gryllidae, Oecanthinae)

This slender and yellowish cricket called on top of low grass or on small bushes in July and August. The calling song, recorded at 22ºC, consisted of long echemesequences (figs. 10A–10B). The duration of each echeme varied between 800 and 1300 ms, at a repetition rate of about 0.6/s, and the gap between consecutive echemes varied from 400 to 500 ms. Each echeme was composed of 18–29 syllables at the repetition rate of about 22/s (figs. 10C–10D). Each syllable lasted about 32 ms and the gap between successive syllables was about 10 ms. The frequency of the carrier wave was about 2.3 kHz (fig. 10E).

Gryllotalpa vineae Bennet–Clark, 1970 (Gryllotalpidae, Gryllotalpinae)

Like most mole–crickets, this species produces its song from a specially made singing burrow, with a pair of short horn–shaped passages, leading to two entrance holes. The song is very

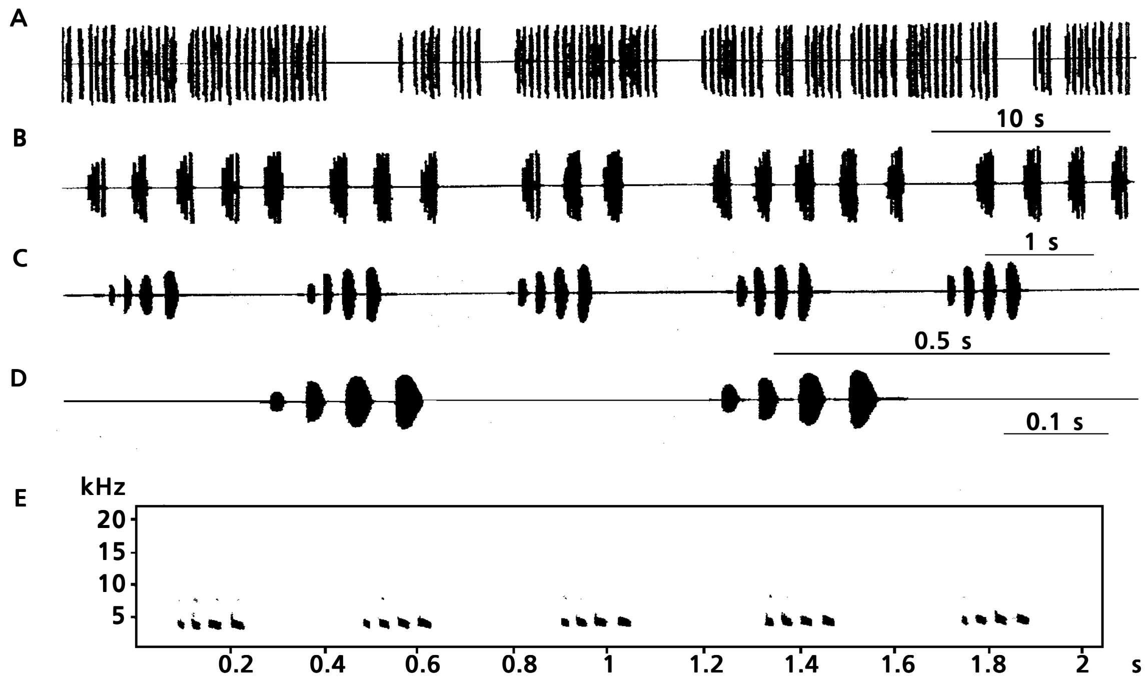

Fig. 7. Oscillograms and sonagram of the calling song of a male of *Gryllus campestris* at 20°C: A. 1 min.; B. 10 s; C. 1.6 s; D. 1 s; E. Sonagram, showing the frequency of the carrier wave at about 4 kHz.

Fig. 7. Oscilogramas y sonograma del canto de llamada del macho de Gryllus campestris *a 20°C: A. 1 min.; B. 10 s; C. 1,6 s; D. 1 s; E. Sonograma que muestra la frecuencia de la onda portadora a 4 kHz.*

loud and shrill, audible from a distance of even 600 m. The calling song, recorded at 17°C, was composed of syllables lasting 10–20 ms each and repeated at the rate of about 54/s (fig. 11). The gap between the syllables was 7–9 ms. The dominant frequency was about 3 kHz (fig. 11E). This mole–cricket is very close to *Gryllotalpa gryllotalpa* (Linnaeus), from which it is easily separated by the frequency of the carrier wave, which is below 2 kHz in *G. gryllotalpa.*

Omocestus raymondi (Yersin, 1863) (Acrididae, Gomphocerinae)

This grasshopper was recorded in September, in the low grasses and called during daylight of warm days. The calling song (fig. 12), recorded at 30° C, consisted of isolated echemes, repeated at irregular intervals, normally from 8 to 10 s, and lasting 1.7–1.8 s each. Each echeme was composed of about 24 syllables (downstroke hemisyllables) repeated at the rate of about 15/s. Each echeme begins quietly, rapidly increasing in amplitude (fig. 12C). Each downstroke hemisyllable, lasting 60–70 ms, had a characteristic pattern of 3–4 gaps, which became obscured towards the end of the echeme (figs. 12D–12E). The range of audible frequencies of the calling song varied at the start of the echeme from about 6-10 kHz to 4–19kHz at a later phase (fig. 12F).

Euchorthippus pulvinatus gallicus Maran, 1957 (Acrididae, Gomphocerinae)

The calling song of this grasshopper was recorded on low grass and during the daytime in June. It was recorded at 27°C and consisted of sequences of echemes regularly repeated at the rate of about two per second and lasting 106–130 ms each (figs. 13A–13C). Each echeme was composed of about seven syllables, which slowly increased in amplitude towards the end; the syllables were repeated at the rate of about 45/s, the last two or three syllables having two gaps each (figs. 13D–13F). The audible frequencies of the calling song ranged from about 4 to 13 kHz (fig. 13G).

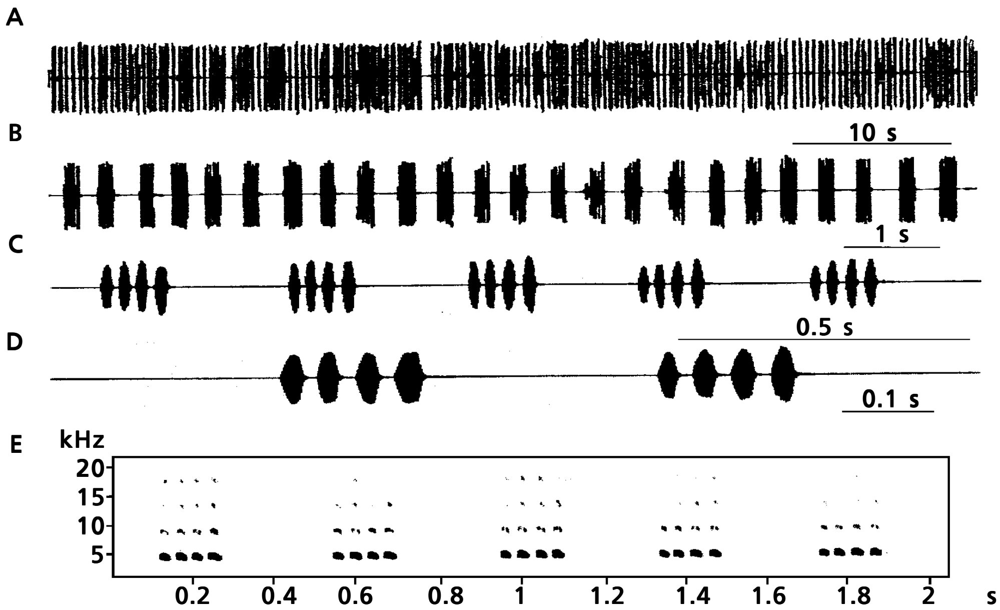

Fig. 8. Oscillograms and sonagram of the calling song of a male of *Gryllus bimaculatus* at 27ºC: A. 1 min; B. 10 s; C. 1.6 s; D. 1 s; E. Sonagram, showing the frequency of the carrier wave at about 4.5 kHz.

Fig. 8. Oscilogramas y sonograma del canto de llamada del macho de Gryllus bimaculatus *a 27ºC: A. 1 min; B. 10 s; C. 1,6 s; D. 1 s; E. Sonograma que muestra la frecuencia de la onda portadora a 4,5 kHz.*

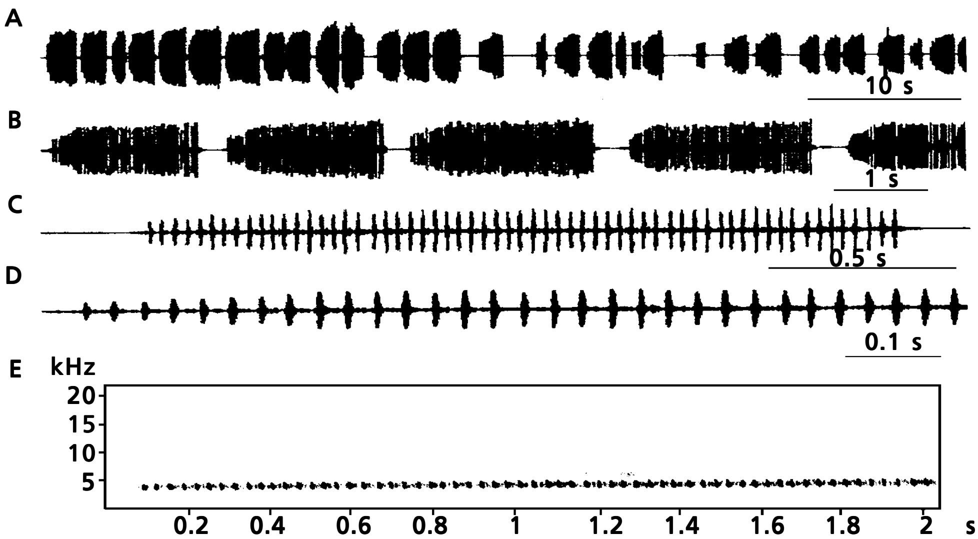

Fig. 9. Oscillograms and sonagram of the calling song of a male of *Nemobius sylvestris* at 29ºC: A. 1 min.; B. 10 s; C. 2.4 s; D. 1 s; E. Sonagram, showing the frequency of the carrier wave at about 3.8 kHz.

Fig. 9. Oscilogramas y sonograma del canto de llamada del macho de Nemobius sylvestris *a 29ºC: A. 1 min.; B. 10 s; C. 2,4 s; D. 1 s; E. Sonograma que muestra la frecuencia de la onda portadora a 3,8 kHz.*

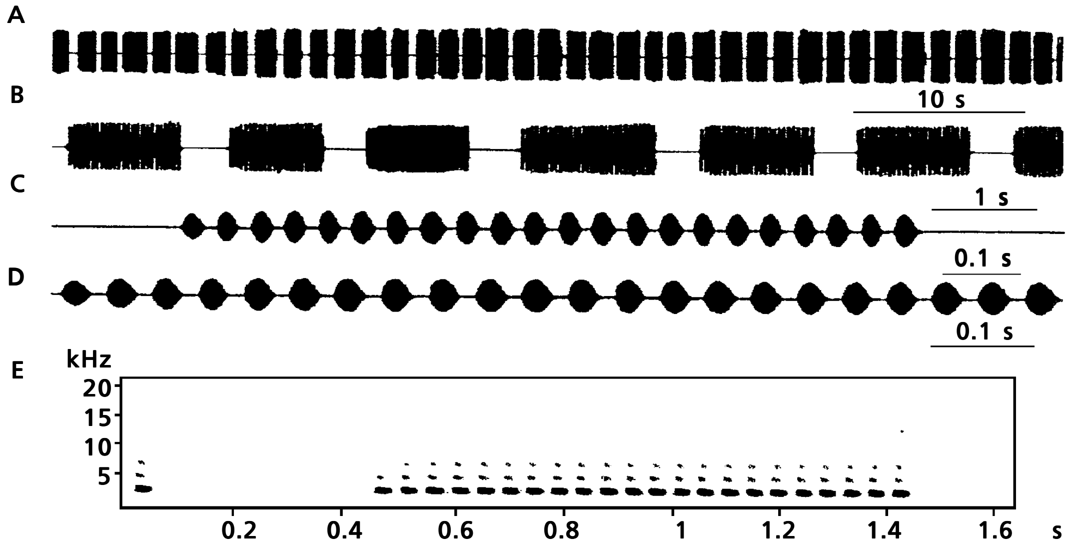

Fig. 10. Oscillograms and sonagram of the calling song of a male of *Oecanthus pellucens* at 22ºC: A. 1 min.; B. 10 s; C. 1.3 s; D. 1 s; E. Sonagram, showing the frequency of the carrier wave at about 2.3 kHz.

Fig. 10. Oscilogramas y sonograma del canto de llamada del macho de Oecanthus pellucens *a 22ºC: A. 1 min.; B. 10 s; C. 1.3 s; D. 1 s; E. Sonograma que muestra la frecuencia de la onda portadora a 2,3 kHz.*

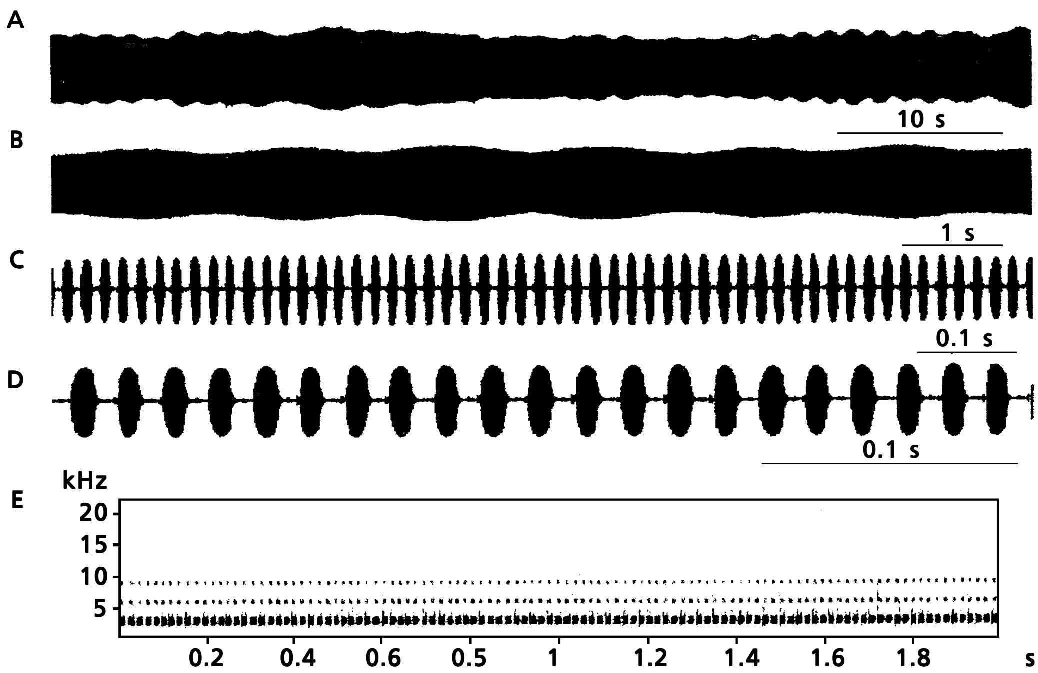

Fig. 11. Oscillograms and sonagram of the calling song of a male of *Gryllotalpa vineae* at 17ºC: A. 1 min.; B. 10 s; C. 1 s; D. 0.4 s; E. Sonagram, showing the frequency of the carrier wave at about 3 kHz.

Fig. 11. Oscilogramas y sonograma del canto de llamada del macho de Gryllotalpa vineae a *17ºC: A. 1 min.; B. 10 s; C. 1 s; D. 0,4 s; E. Sonograma que muestra la frecuencia de la onda portadora a3 kHz.*

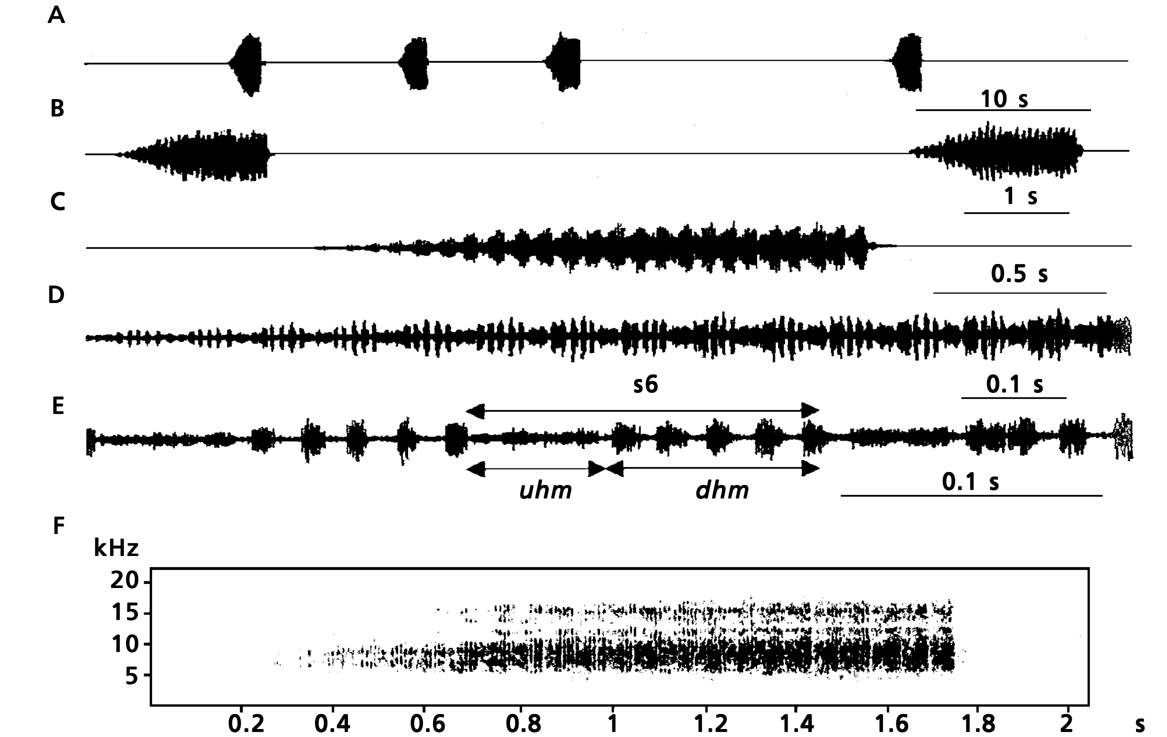

Fig. 12. Oscillograms and sonagram of the calling song of a male of *Omocestus raymondi* at 30°C: A. 1 min.; B. 10 s; C. 3.5 s; D. 1 s; E. 0.4 s; *s6*. Sixth syllable; *uhm*. Upstroke hemisyllable; *dhm*. Downstroke hemisyllable; F. Sonagram, showing the audible frequencies of the calling song varying from about 6–10 kHz at the beginning of the echeme to 4–19 kHz at a later phase.

Fig. 12. Oscilogramas y sonograma del canto de llamada del macho de Omocestus raymondi *a 30°C: A. 1 min.; B. 10 s; C. 3,5 s; D. 1 s; E. 0,4 s;* s6. *Sexta sílaba; uhm. Hemisílaba ascendente;* dhm. *Hemisílaba descendente; F. Sonograma que muestra las frecuencias audibles del canto de llamada que varían entre 6 y 10 kHz al principio del "echeme" y entre 4 y 19 kHz en la fase final.*

Discussion

There are a few previous descriptions of the songs of Portuguese Orthoptera in Portuguese males e.g., in RAGGE & REYNOLDS (1998). However, the songs here presented are the first descriptions of the acoustic parameters and behaviour of the Portuguese populations of 12 species of the 13 found at the field station “Herdade da Ribeira Abaixo”, nearby Grândola (southern Portugal). Thesse descriptions are of special value at the species level, since calling songs are species specific and are important components of the specific mate recognition system in orthopterans (PERDECK, 1957; PATERSON, 1985; REYNOLDS, 1988; RAGGE & REYNOLDS, 1998). Therefore, these songs can be a quick, easy and very practical way of species identification in the field, without the need for collecting, killing and mounting specimens. Calling songs are also of particular value for determining the geographic boundaries of the species ranges (GREEN, 1995).

Three closely related species of the genus *Platycleis* were found at the field station: *P. sabulosa, P. affinis* and *P. intermedia,* the first being a new record for Portugal. The temporal patterning of their calling songs differs greatly among species, offering good characters for their taxonomic separation, as RAGGE (1990) has also emphasized: for instance, the echemes vary from disyllabic (*P. intermedia*), penta– or hexasyllabic (*P. sabulosa*) to comprising several scores of syllables (*P. affinis*). Differences in the temporal patterning also occur in the remaining Tettigoniidae and in the Acrididae here studied. Oscillograms are thus very convenient for portraying the calling songs and for discriminating most of these species.

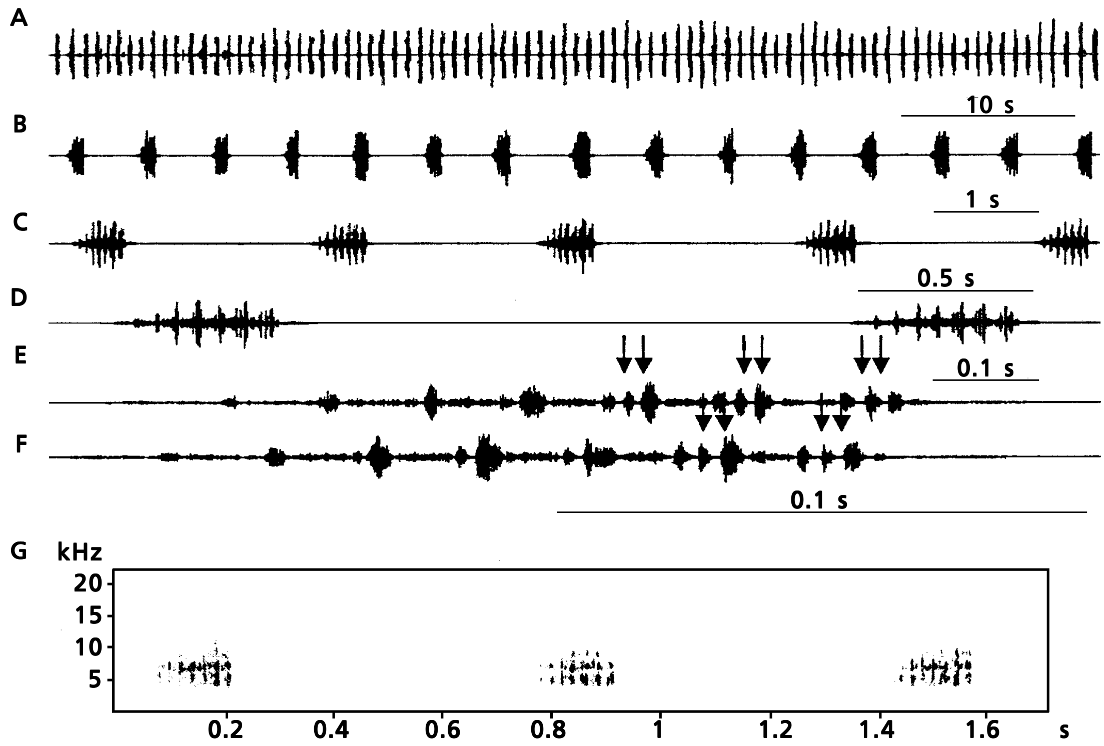

Fig. 13. Oscillograms and sonagram of the calling song of a male of *Euchorthippus pulvinatus gallicus* at 27°C: A. 1 min.; B. 10 s; C. 3.5 s; D. 1 s; E. 0.2 s, an echeme with 6 gaps; F. 0.2 s, an echeme with 4 gaps; g. Sonagram, showing the audible frequencies of the calling song ranging from about 4 to 13 kHz; ↓Gap.

Fig. 13. Oscilogramas y sonograma del canto de llamada del macho de Euchorthippus pulvinatus *gallicus a 27°C: A. 1 min.; B. 10 s; C. 3,5 s; D. 1 s; E. 0,2 s, un "echeme" con seis intervalos; F. 0,2 s, un "echeme" con 4 intervalos; g. Sonograma que muestra las frecuencias audibles del canto de llamada que oscila entre 4 y 13 kHz; ↓Intervalo.*

In the genus *Gryllotalpa,* the situation is, however, different. Two species occur in western Europe: *G. gryllotalpa* (Linnaeus) and the species here found *G. vineae* Bennet–Clark. These two mole-crickets are, in fact, close morphologically and it is probable that the previous citations of *G. gryllotalpa* to Portugal (e.g., AIRES & MENANO, 1916; SEABRA, 1939, 1942) should refer instead to *G. vineae.* Temporal parameters of the calling song are rather variable in both species, being temperature dependent. However, the dominant frequency carrier wave appears to be much more constant within each species, being below 2 kHz in *G. gryllotalpa* and at least 3 kHz in *G. vineae* (RAGGE & REYNOLDS, 1998). As such, this is a nice example of frequency seemingly being of great taxonomic importance for discrimination of sibling species. Sonagrams are thus quite useful here for specific identification and delimitation.

In the pair of closely related species of the genus *Gryllus* the temporal patterning of the calling songs is very similar. However, in *G. campestris* the four hemisyllables tended to increase in a *crescendo* throughout the echeme, in contrast with *G. bimaculatus,* where all four were of the same amplitude. *G. campestris* also showed a dominant frequency slightly lower than in *G. bimaculatus*. In the two remaining gryllids, *Nemobius sylvestris* and *Oecanthus pellucens*, which are quite distinct morphologically, there was also some similarity in the temporal patterning of the songs. They are, however, readily separated by temporal parameters such as the structure and duration of the echemes. Moreover, the carrier frequency is also discriminatory, since it is about 3.8 kHz in *N. sylvestris* and 2.3 kHz in *O. pellucens*

In short, this study suggests that oscillograms were in general very useful for portraying the calling songs of the species here studied. On the other hand, except for Gryllidae and Gryllotalpidae, sonagrams from audio recordings may give a misleading impression of the frequency spectrum of the song, which in Acrididae and Tettigoniidae extends well into the ultrasonic range, and in some Tettigonniidae is mainly ultrasonic. For Gryllidae and Gryllotalpidae, the carrier frequency can be measured more accurately from fast oscillograms than from sonagrams (D. R. Ragge, pers. comm.). Nevertheless, sonagrams are a useful addition to song analysis, especially if they include the full frequency spectrum of the song. Therefore, the simultaneous use of both oscillograms and sonagrams is encouraged.

Finally, as previously mentioned, one species found at the field station —*Platycleis sabulosa* Azam—, is here recorded for the first time from Portugal. Moreover, considering the small geographic area investigated many more new records are yet to be found in this country and hence further studies dealing with these insects should be encouraged.

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