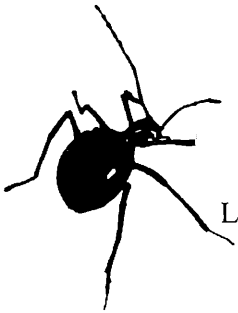

LJUBLJANA, JULY 2000 Vol. 8, No. 1: 21-26

SOUND EMISSIONS OF *PAGIPHORA ANNULATA* (HOMOPTERA: CICADOIDEA: TIBICINIDAE) - A PRELIMINARY REPORT

Matija GOGALA, Tomi TRILAR
Prirodoslovni muzej Slovenije, Prešernova 20, SI-1001 Ljubljana, Slovenia

Abstract - Songs of *Pagiphora annulata* (Brullé 1832) were recorded in 1998 in some localities in Republic of Macedonia, which is at the northwestern edge of the distribution area of this species. We heard and recorded only one type of calling song with 2.1 to 2.9 s long phrases, comprising 7 to 10 echemes whose duration and intensity increases toward the end of a phrase. Repetition frequency of echemes in a phrase is 3 ± 0.5 Hz. The frequency band of these sounds is surprisingly low for small cicadas, from 3 to 4.5 kHz with the peak around 3.9 kHz. The second part of the last 3 to 5 echemes is suddenly louder and sharp to our ears, spectrograms in these parts show a broader spectrum. Oscillographic analysis of such echemes in an extended time scale shows additional short sound pulses only roughly synchronised with the regular tymbal pulses. The mechanism of sound production of these short and loud pulses is not yet known, but vibrations of wings are evident. Therefore, we assume that these pulses are crepitations produced by the contact of vibrating wings with the abdomen.

KEY WORDS: *Pagiphora annulata*, Cicadoidea, Tibicinidae, song, tymbal, crepitation, bioacoustics

Izvleček PREDHODNO POROČILO O NAPEVIH ŠKRŽATOV VRSTE *PAGIPHORA ANNULATA* (HOMOPTERA: CICADOIDEA: TIBICINIDAE)

Napeve škržatov vrste *Pagiphora annulata* (Brullé 1832) smo posneli leta 1998 v Makedoniji, kjer je verjetno najsevernejše in najzahodnejše najdišče te vrste. Ugotovili smo en pozivni napev, ki sestoji iz 2.1 do 2.9 s dolgih fraz, ki so sestavljene iz 7 do 10 ehemov, katerih dolžina in intenziteta naraščata proti koncu fraze. Ponavljalna frekvenca pojavljanja ehemov v frazi je 3 ± 0.5 Hz. Frekvenčno območje večine ehemov je presenetljivo nizko za razmeroma majhne škržate od 3 do 4.5 kHz z vrhom okoli 3.9 kHz. Pri zadnjih treh do petih ehemih v frazi se drugi del ehema ojača in zvočni spekter se spremeni v širokopasovni. Zvok tega dela napeva je za naše uho rezek. Analiza signalov v raztegnjeni časovni skali pokaže, da se poleg rednih timbalnih signalov v teh delih ehemov pojavijo dodatni kratki impulzi, ki so le približno sinhroni z rednimi timbalnimi pulzi. Način produkcije teh signalov še ni raziskan, opazno pa je ob tem tresenje kril. Zato domnevamo, da nastanejo ti dodatni pulzi kot krepitacija ob stiku kril z deli abdomna.

KLJUČNE BESEDE: *Pagiphora annulata*, Cicadoidea, Tibicinidae, napev, timbal, krepitacija, bioakustika

Introduction

During investigations of Cicadoidea fauna in Macedonia in 1998 in some localities we found the cicadas *Pagiphora annulata* (Brullé 1832) and recorded their sound emissions. The only description of the song of any cicada of this genus had been published by Boulard (1992) for *Pagiphora yanni* together with the description of that species. In the following report we show the species specificity, unusual physical characteristics of the song, and the evidence for two different sound production mechanisms in *P annulata*.

Material and Methods

We found *P. annulata* in the vicinity of the villages Cerovo and Nova Breznica near Skopje, around Gradište near Ohrid, and in Slandol near Ulanci between June 29th and July 7th, 1998. Previously, Hans Duffels from Amsterdam collected this species near Skopje (20 km W) and on the mountain Pelister (personal communication). Therefore we assume that this cicada species has a wide distribution in Macedonia. These localities are at the NW border of its distribution area.

Sounds were recorded digitally using a Telinga Pro III stereo and Pro III mono microphones and DAT recorders Sony TCD-D3, TCD-D7 and TCD-D10 and a high speed (HS) DAT recorder Pioneer D-C88 (sampling rate 96 kHz) connected with a Telinga Pro 5 Science microphone sensitive also in the ultrasonic range.

The digital recordings were transferred to the hard disk of a Power Macintosh G3/233 computer through an Audiomedia III card. Software used for viewing, editing and analysing the song signals was Digidesign ProTools 4.1 and Canary 1.2.

For simple statistical evaluation we used the Apple Works 5 program.

Some specimens, also some recorded ones, were collected at these locations and are now in the Hemiptera collection of the Slovenian Museum of Natural History (PMSL).

Results

The basic song pattern are 2.1 to 2.9 s long phrases composed of 7 to 10 echemes increasing in duration and intensity toward the end of a phrase (Fig. 1c-e). Repetition rate of echemes is 3 ± 0.5 Hz. Such phrases are repeated irregularly, usually after an interval of about 2 to 10 seconds (Fig. 1e).

The surprising characteristic of these sound emissions is their low frequency range of 2.5 to 6 kHz (-20 dB band) with a peak around 3.9 kHz (Fig. 1a). A second part of the 3 to 5 last and loudest echemes differs in a broader spectrum and higher intensity (Fig. 1b-d, 2). Observing the details of oscillograms and sonagrams in an extended time scale, clearly shows that in these parts of a song new, short pulses with a broader frequency spectrum appear in addition to the normal regularly repeating tymbal pulses (Fig. 2c, d). These loud and short pulses are only roughly synchronised with the tymbal ones, the first ones appear in the middle of the interval between them and the following ones are better synchronised and usually precede the tymbal pulses (Fig. 2c, d).

Observations of animals in cages have shown that during this period of loud and for our ears sharp "distorted" sounds, the cicadas vibrate the wings. Unfortunately, we do not yet know further details about this additional sound production mechanism but assume that these sounds are crepitations produced during contact of vibrating wings with the corresponding parts of the abdomen.

Discussion

Boulard (1992) described in *Pagiphora yanni* two different songs, a calling song and a courtship song with additional distinct precopulatory signals. During our field work we did not observe or record in *P annulata* any other song pattern than the one described above. This song differs from both songs of *P. yanni* in the amplitude modulation pattern of phrases and also in other time and frequency parameters. Common characteristics of songs of both species are the relatively low frequency range for such small cicadas (4 - 9 kHz in *P. yanni* and 2.5 - 6 kHz in *P. annulata*) and at least in some parts of a song the appearance of an additional sound producing mechanism, as Boulard also mentions occurrence of wing movements during some sections with a broader frequency spectrum in *P. yanni.*

Cicadas of approximately the same size as *Pagiphora annulata* such as *Cicadetta tibialis* (Gogala et al., 1996) or *Tettigetta brullei* (Popov et al., 1997) all show a much higher frequency range, extending even into the ultrasonic part of a spectrum, which one would expect of a resonant body of this size. There are some other cicada species with a similar or even lower frequency ranges but only exceptionally with a similar body size (e.g. Popov, 1989). What is the reason for this unusual characteristic of the *P. annulata* song, one can only guess. It is surprizing that they can be found in similar habitats and at the same time on the same bushes as e.g. high pitched *Cicadetta tibialis*. On the

other hand, it is known that most species of cicadas have their maximum auditory sensitivity in the same range as the sound emissions of *Pagiphora* between 3 and 5 kHz (Popov, 1990).

The details of the sound production mechanism in *Pagiphora annulata* should be studied in detail in the future, probably using ablation methods and high frequency video recording. Nevertheless, according to this study and many others (e.g.: Boulard, 1995; Gogala and Trilar, 1998) there is no doubt that for sound production many cicadas use more than one basic mechanism, which in this case is a tymbal, a well developed structure with 9 to 10 long ribs.

Acknowledgements

The Ministry of Culture and Ministry of Science and Technology (project J1-7409) of the Republic of Slovenia financially supported our field work in Macedonia in 1998. In Macedonia, we received important support by the former director of the Natural History Museum in Skopje, Dr. Svetozar Petkovski and especially by our colleagues and friends Vlado Krpač and Toše Ivanovski. We are grateful also to Dr. Andrej Gogala from our Museum for careful preparation of collected animals.

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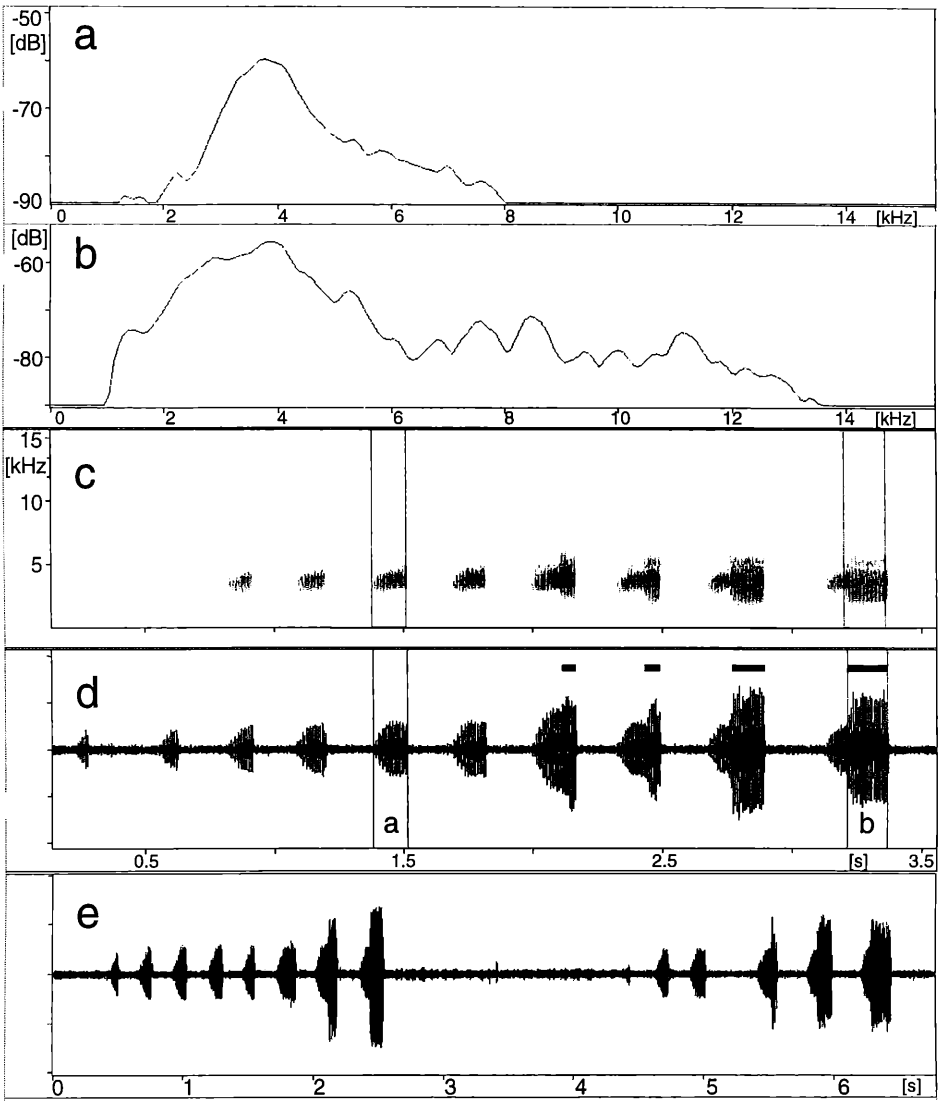

Fig. 1: Song of *Pagiphora annulata:* a and b - Frequency spectra of selections shown in oscillogram (d) and sonagram (c). c - Sonagram of the phrase shown also as an oscillogram in d; selection a comprises a "normal" echeme probably produced by tymbals, and selection b a part of last echeme in a phrase characterised by a broader frequency spectrum and different sharp sound. Parts of the last 4 echemes with such characteristics are marked with black bars. e - 2 phrases of song in a compressed time scale.

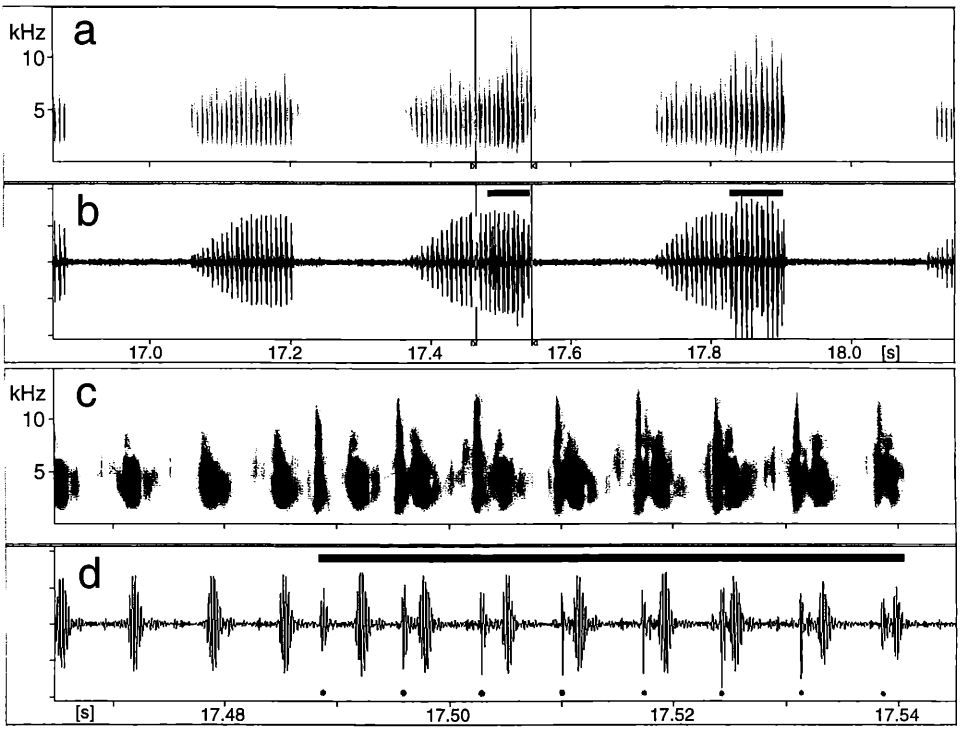

Fig. 2: Song of *Pagiphora annulata:* Oscillograms (b and d) and sonagrams (a and c) of a selected part of a phrase (a, b) and a marked part of one echeme from this selection with the appearance of additional broad band pulses (c, d) of unknown origin but probably produced by wing banging. Short additional pulses are marked by filled circles and the parts of echemes with a broad band spectrum and such additional pulses with black bars.

Received / Prejeto: 3. 4. 2000