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BIOACOUSTICS OF SINGING CICADAS OF THE WESTERN PALAEARCTIC: *TETTIGETTA DIMISSA* (HAGEN) (CICADOIDEA: TIBICINIDAE)

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Abstract Songs of the cicada *Tettigetta dimissa* Hagen from Slovenia, Croatia and Macedonia were investigated and compared with previous descriptions based on specimens from the Caucasus region. Sound emission consists of two types of song, animals can switch between them without interruption. The first type consists of a sequence of short equal phrases composed of a series of 5 - 6 short echemes and one long echeme. The second type is very complex and is built of four segments. The first comprises a series of short echemes, in the second segment the pattern is similar to the first type of song but the number of short echemes and the duration of the long ones gradually increases, and in the third segment the echemes eventually fuse into a continuous buzzing sound. After a short pause, there follows a final long echeme, and after a short interval the whole sequence starts again. The main frequency band of sound emission is between 10 and 18.5 kHz with the peak around 13 kHz. There is also a second, less intense (-20 dB) frequency band which peaks around 6 kHz. Despite the slightly lower frequencies of the song as compared to other small singing cicadas from the same region, the use of ultrasonic detectors for field research on these cicadas can be very useful. Songs of *T. dimissa* from Slovenia and the Balkans show the same general pattern as the animals from the Caucasus. Nevertheless, the short echeme repetition period and the long echeme duration of song type 1 are longer, and the length of the first segment of song type 2 is shorter in animals from the Caucasus.

KEY WORDS: Cicadoidea, Tibicinidae, *Tettigetta dimissa*, acoustics

Izvleček - BIOAKUSTIKA POJOČIH ŠKRŽATOV ZAHODNEGA PALEARKTIKA: *TETTIGETTA DIMISSA* (HAGEN)(CICADOIDEA: TIBICINIDAE)

V članku opisujemo napeve prezrtega škržata (*Tettigetta dimissa* Hagen) iz Slovenije, Hrvaške in Makedonije in jih primerjamo z napevi iste vrste z območja Kavkaza. Samci vrste *Tettigetta dimissa* imajo dva napeva, ki lahko prehajata eden v drugega brez prekinitve. Prvi sestoji iz zaporedja enakih fraz, ki jih tvori 5-6 kratkih ehemov in en dolgi ehem. Drugi napev je zelo kompleksen in sestoji iz štirih segmentov. Prvi segment sestavlja zaporedje kratkih ehemov, sledi drugi segment, ki spominja na prvi napev in sestoji iz fraz s kratkimi ehemi in enim dolgim, vendar se število kratkih ehemov in dolžina dolgih polagoma povečuje, ponavljalna frekvenca kratkih pa znižuje, dokler se v tretjem segmentu ehemi ne zlijejo v enakomerno brenčanje. Temu sledi kratka pavza in en zaključni dolg ehem in nato se lahko po krajšem presledku vsa sekvenca ponovi. Glavni frekvenčni pas obeh napevov je med 10 in 18.5 kHz z vrhom okoli 13 kHz. Poleg tega obstaja še stranski nižji frekvenčni pas emisije z vrhom okoli 6 kHz (-20 dB) kot pri večini ostalih sorodnih škržatov. Čeprav so frekvence napevov v primerjavi z drugimi majhnimi vrstami škržatov nekoliko nižje, je za detekcijo na terenu zelo koristna uporaba ultrazvočnega detektorja. Napevi živali s Kavkaza imajo podobno zgradbo obeh napevov kot škržati iz Slovenije in Balkana, vendar imajo pri prvem napevu kavkaške živali nižjo ponavljalno frekvenco kratkih ehemov in daljše dolge eheme, pri drugem napevu pa sta predvsem dolžina prvega segmenta in cele sekvence krajša v primerjavi z živalmi iz Slovenije in Balkana.

KLJUČNE BESEDE: Cicadoidea, Tibicinidae, *Tettigetta dimissa*, akustika

Introduction

During the last few seasons we investigated the sound emissions of singing cicadas in Slovenia, Croatia and Macedonia and compared the results where possible with previously investigated populations in parts of the former USSR and more recently in the Western Mediterranean (Gogala et al., 1996, Gogala & Popov, 1997, Popov et al. 1997, Gogala & Trilar, 1998 and 1999). In 1994 for the first time *Tettigetta dimissa* Hagen was one of the species found in Slovenia during our joint investigations (Schedl, 1986, Gogala & Gogala, 1999). Popov (1975) previously described sound emissions of this species from the Caucasus region, but there were no data about the song characteristics of this species from the Mediterranean region.

Material and Methods

Cicadas, *Tettigetta dimissa* (Hagen 1856) (Fig. 1), were investigated in the warm regions of Slovenia (Karst and seaside), Croatia (Istria, Kvarner and Dalmatia) and in Macedonia in the years 1993 - 1998. The song parameters were compared with the previously investigated songs of this species from the Caucasus region (Popov 1975 and unpublished data).

The acoustic recordings in Slovenia, Croatia, and Macedonia were made in the field using digital techniques in the human sonic range using a TELINGA PRO III and PRO V parabolic stereo microphone (parabola diameter: 57 cm) connected to SONY DAT-recorders TCD D3, TCD D7, TCD-D10 (sampling rate 48 kHz, 16 Bit dynamic range) and a Pioneer DC-88 DAT in HS mode (sampling rate 96 kHz). All recordings were made during the hot time of day in ambient temperatures between 25 - 35°C.

For detection of high pitched sounds of this species we used also the ultrasonic microphone of a S-25 Ultra Sound Advice bat detector mounted on a Telinga parabola. The output of the detector was connected to a DAT tape recorder. This system was described by Popov et al. (1997).

In the lab, DAT recordings were transferred to the Hard Disk of a Power Macintosh G3/233 computer through an Audiomedia III sound card. Software used for viewing, editing and analyzing the song signals were Digidesign ProTools 4.1, and Canary 1.2.

The Statview 4.5 program was used for graphic presentation and statistical evaluation of temporal parameters.

Voucher specimens of cicadas from Slovenia, Croatia, and Macedonia are preserved in the collection of the Slovenian Museum of Natural History in Ljubljana, and specimens from the Caucasus region in the collection of the Zoological Museum in St.Petersburg, Russia.

Macrophotographs were made with a WILD M8 stereomicroscope with Photoautomat.

Results

Calling sounds produced by *T. dimissa* males contain two types of songs which are alternatively emitted.

Song Type 1 can last from several seconds to many minutes. It consists of repeated phrases with sequences of 5 - 6 short echemes and one long echeme (Fig. 2a). Short echemes are 4.7-6.3 ms in duration. They each contain 4 very short pulses (0.8-1.1 ms), produced by 1 in and out action of the left and right timbals working in alternation with a phase shift of 1.5-1.7 ms (Fig. 2b). Long echemes are produced by several successive actions of both tymbals working at a rate of 115-142 Hz, so that the pulses of each next action (in or out of the opposite tymbal) appear about 1-1.5 ms after the preceeding one (Fig. 2c). The result is a continuous series of short pulses repeated at a mean rate of 450-650 Hz. The long echeme duration varies from 25.8 to 59.3 ms.

The distribution of durations is not normal (Fig. 4a). It has 3 peaks reflecting a stepwise change during singing. The mean repetition rate of long echemes is 5.7 Hz; of short echemes, 43.1 Hz. The distribution of the long echeme repetition period also has 3 peaks (Fig. 4b) reflecting the stepwise changes of their duration, and that of short echemes has a single asymmetric peak (Fig. 4c).

Animals from different regions of Slovenia have a similar song type 1, but those from the Caucasus are characterised by relatively longer long echemes (Fig. 4d) and longer repetition periods of short echemes, comparable only to those of 2 animals

recorded from Premantura, Croatia (Fig. 4e).

Song type 2 usually also lasts for several minutes. It is comprised of a series of complicated sequences. Each sequence consists of 4 segments which follow successively in a strictly fixed order (Fig. 3a) and its total duration varies in the range of 4.5-9.4 s (Fig. 5a). Segment 1 is comprised of an apparently simple series of short echemes (Fig. 3b) similar to the short echemes of song type 1. The duration of this segment is 0.65-2.62 s (Fig. 5b). The repetition period of these short echemes is stable, has a normal distribution, and has a mean value and standard deviation of 31.1 ± 5.8 ms (repetition rate 32.2 Hz) (Fig. 5c).

Segment 2 consists of alternating long and short echemes (Fig. 3c). Again, here the short echemes are similar to those of song type 1 but their repetition rate gradually increases, reaching the highest values of 120-140 Hz (Fig. 6f). Long echemes here increase in duration from the beginning to the end of the segment, from about 13-16 ms at the beginning to 60-71 ms at the end. Their mean duration is 42.9 ± 10.8 ms (Fig. 6b), and their mean repetition period is 137 ± 13 ms (Fig. 6c), which means a repetition rate of 7.3 Hz. Segment 2 is also highly variable in duration (Fig. 6a).

Segment 3 sounds continuous to our ears with an internal structure like the long echemes described above, and are generated by sustained repetitive actions of both tymbals (Fig. 3d). The duration of this long echeme varies from 1.55 to 4.0 s (Fig. 7a).

Segment 4 is a single echeme, 70.7 ± 6.9 ms long (Fig. 7c), which appears after a rather stable pause (Fig. 7b) following segment 3 (Fig. 3d). The next song type 2 sequence starts 123 ± 24 ms (Fig. 7f) after the end of the preceeding one.

Animals from different regions of Slovenia, Croatia, and Macedonia have a similar song type 2. Those from the Caucasus are characterised by a song type 2 with shorter sequences (Fig. 5d) and segments 1 (Fig. 5e). All the other parameters are in one cluster with those of Slovenian animals (Figs. 5f, 6d, 7d,e).

Figure 8 shows the main frequency band spectrums in both types of song, ranging between 10– 18.5 kHz, with a peak of intensity around 13 kHz. There is also a side frequency band with a peak around 6 kHz which is about 20 dB lower in comparison to the main peak.

A sample of the sound emissons of *Tettigetta dimissa* can be heard by downloading from the website:

http://www2.arnes.si/~ljprirodm3/cikade.html

Discussion

According to Kudryasheva (1979), the geographic distribution of this species is not well known, and it appears in Fig. 14 of this paper as a series of disjuncts ranging from the southeastern Alps and Sicily through middle Asia to Sichuan, China. During our fieldwork in Slovenia and the Balkans we found this species everywhere in the warmer regions from Slovenia to Macedonia, but we do not know if the distribution in Asia is also continuous. Therefore, a comparison with the song characteristics of animals in the Caucasus region was interesting. From our analysis of song parameters, and comparisons with the previously published data of Popov (1975), it is evident that the

sound emissions of *Tettigetta dimissa* from Slovenia, Dalmatia, Macedonia and the Caucasus do not differ substantially. Probably all these populations belong to the same taxon.

If we accept the present taxonomic status of the genus *Tettigetta,* it is surprizing that the calling song structure of the various species in this genus are so very different. In some species it is a simple repetition of one type of short echeme (as in *Tettigetta argentata* (Fonseca, 1991, Boulard, 1995), it can be similar to the sound patterns of various species of *Cicadetta* (as in the case of *Tettigetta brullei,* Popov et al., 1997), or it can be as complex as in the case of *T dimissa*. From bioacoustic data, one would not conclude that these species belong to a single monophyletic group.

The frequency spectrum of *T. dimissa* songs has slightly lower frequency values compared to other small palaearctic singing cicadas e.g. *Tettigetta brullei*, *Cicadetta tibialis, Cicadetta mediterranea* (Gogala et al., 1996, Gogala & Popov, 1997, Popov et al. 1997). This is probably connected with the size variations among these animals. Nevertheless, an ultrasonic detector, as described by Popov et al. (1997) is of great help in detecting the singing animals of *T dimissa* in the field because of the masking of their songs by louder sound emission of some other cicada species like *Cicada orni* or *Lyristes plebejus.*

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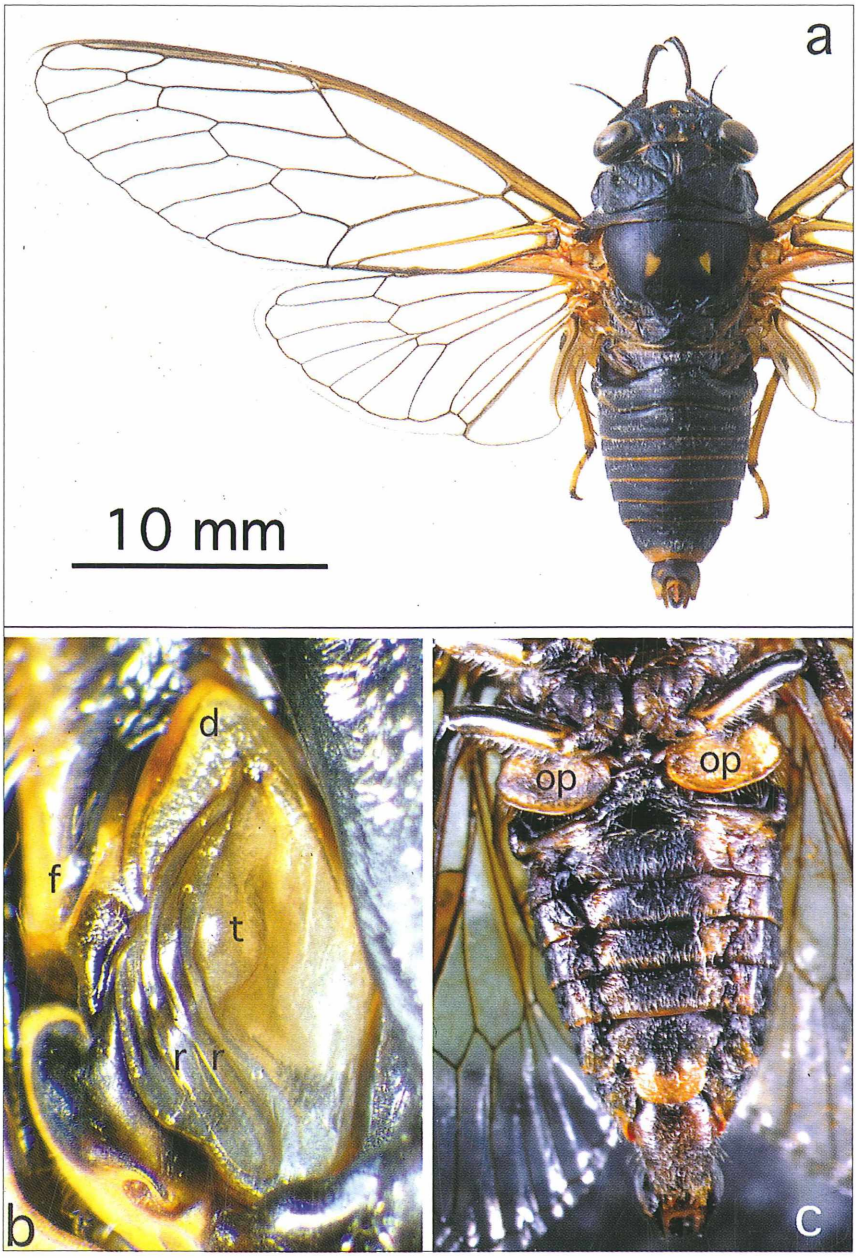

Fig. 1: *Tettigetta dimissa,* male. a - pinned specimen from Kamenjak (Croatia); b - left tymbal with a tymbal plate (t), 2 long ribs (r) and 2 short ones; c - ventral side of the abdomen with opercula (op).

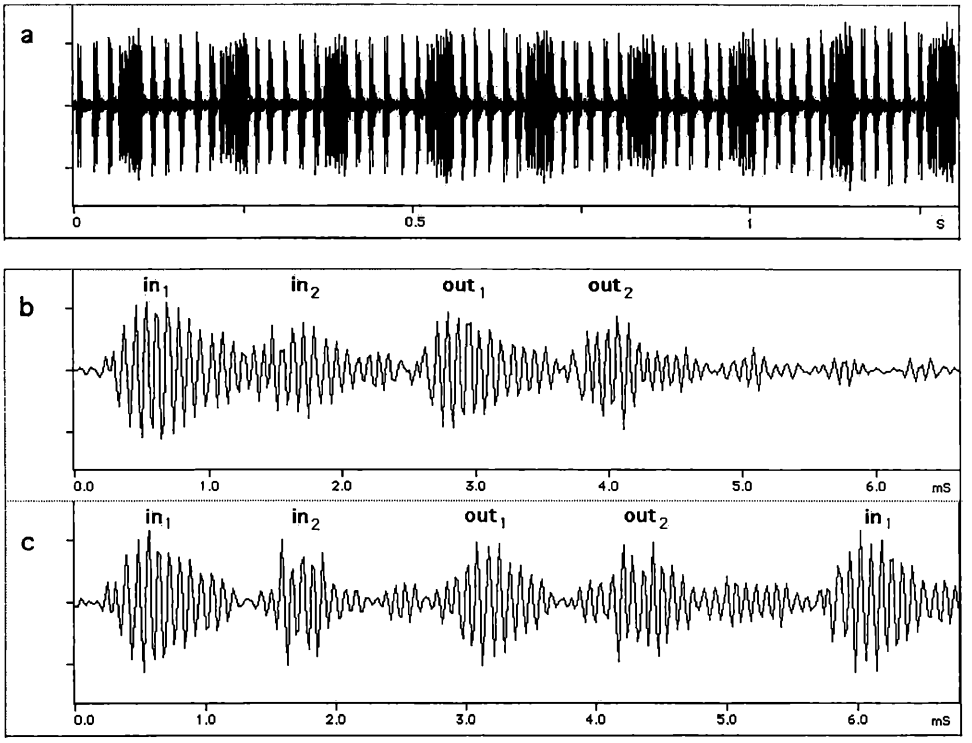

Fig. 2: *Tettigetta dimissa,* oscillograms of song type 1. a - typical song pattern, b - fine structure of a short echeme, each composed of four paired sequential pulses produced by one shifted inward (in) and one shifted outward (out) buckling of the left and right tymbals, c - similar pattern of sequential pulses produced by inward and outward buckling of both tymbals when producing long echemes.

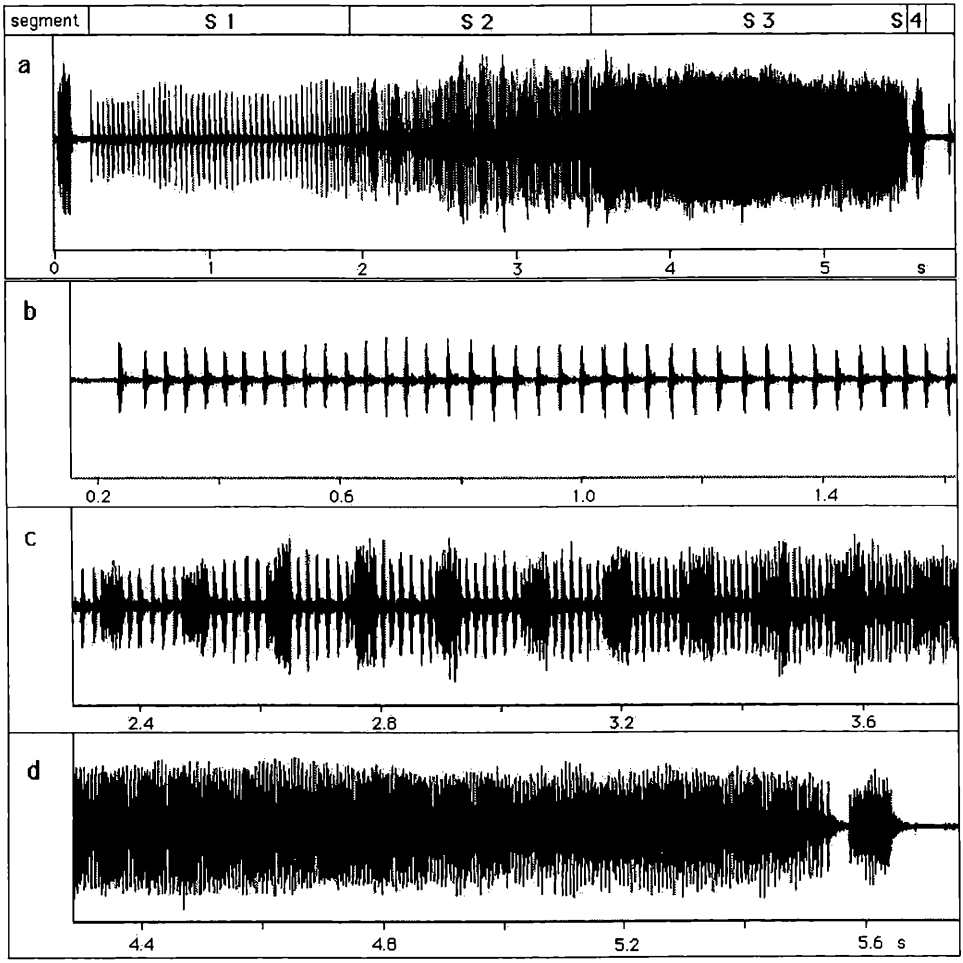

Fig. 3: *Tettigetta dimissa,* oscillograms of song type 2. a - oscillogram showing a typical song pattern of a whole sequence, b - song pattern of segment 1 (S1), c - song pattern of segment 2 (S2), d - song pattern of segments 3 (S3) and 4 (S4).

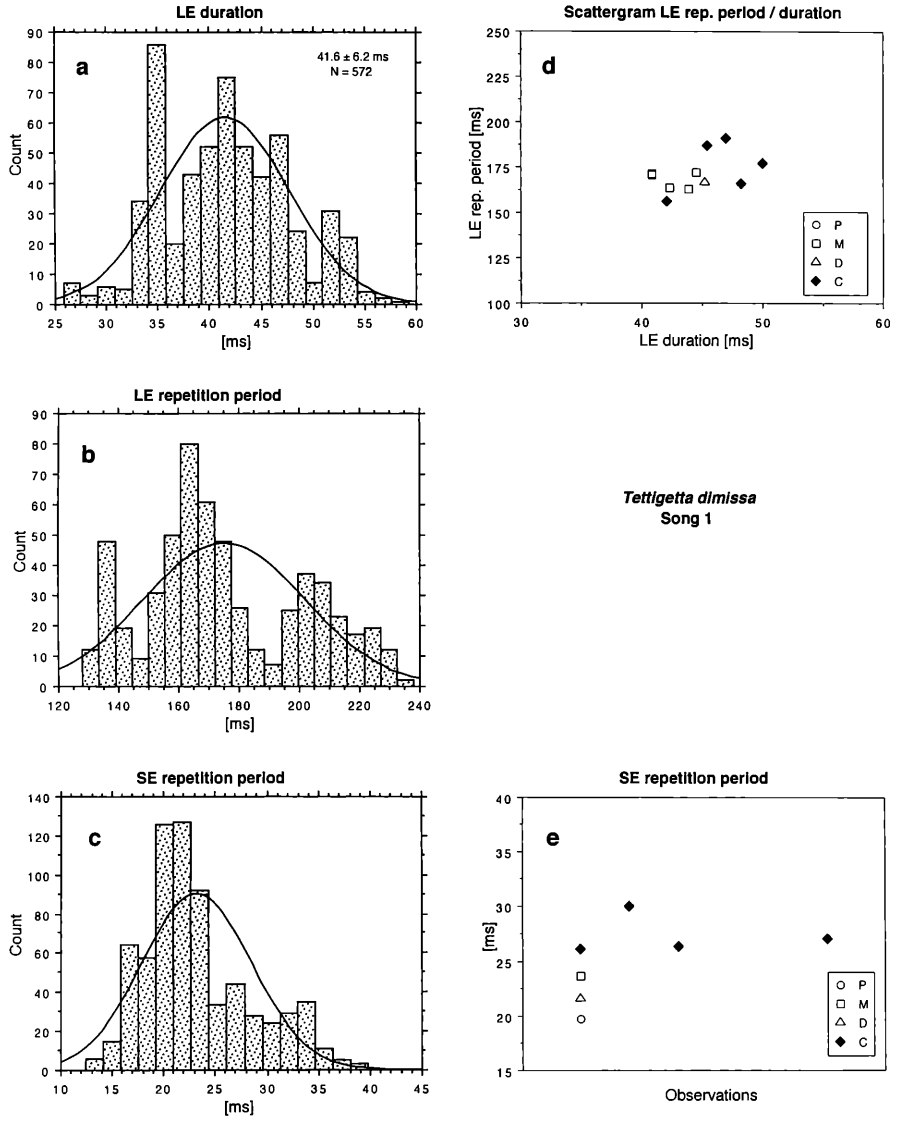

Fig. 4: *Tettigetta dimissa,* time parameters of song type 1. a - c, Histograms showing a statistical distribution of data for long echeme (LE) duration (a), LE repetition period (b) and short echeme (SE) repetition period (c). d - Scattergram showing grouping of means of LE duration versus LE repetition period for animals (N = 16) from different regions (see the scattergram, below); e - univariate scattergram of means of SE repetition period for animals (N = 15) from different regions: P Premantura (Croatia, Istria), M - Macedonia, D - Dragonja (Slovenia) and C - Caucasus.

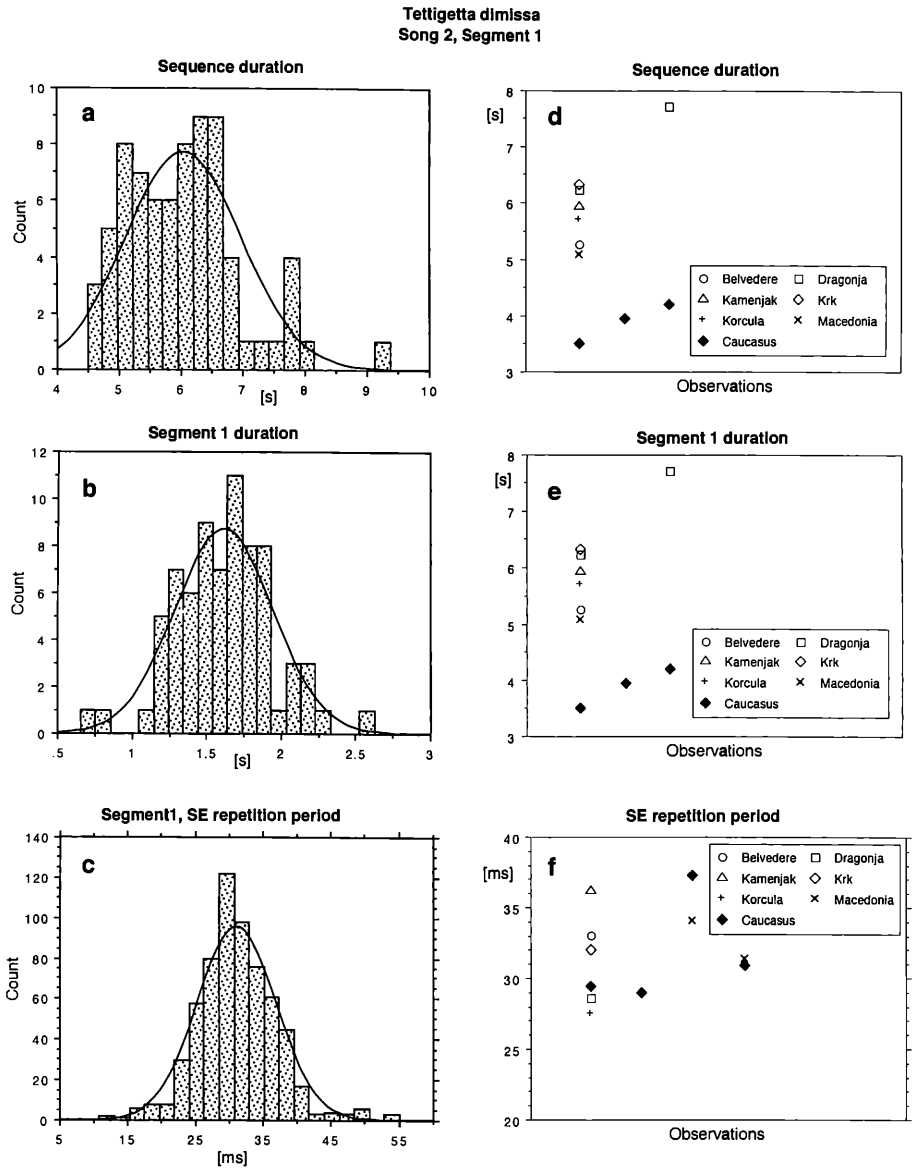

Fig. 5: *Tettigetta dimissa,* time parameters of song type 2, segment 1. a - c, Histograms showing the statistical distribution of data for a whole sequence duration (a), segment 1 duration (b), and short echeme (SE) repetition period (c). d - f, Univariate scattergrams of means of same parameters for single animals (d: N = 20, e: N = 19, f: N = 15) from different locations: Belvedere and Dragonja (Slovenia), Kamenjak, Krk, Korčula (Croatia), Macedonia and Caucasus.

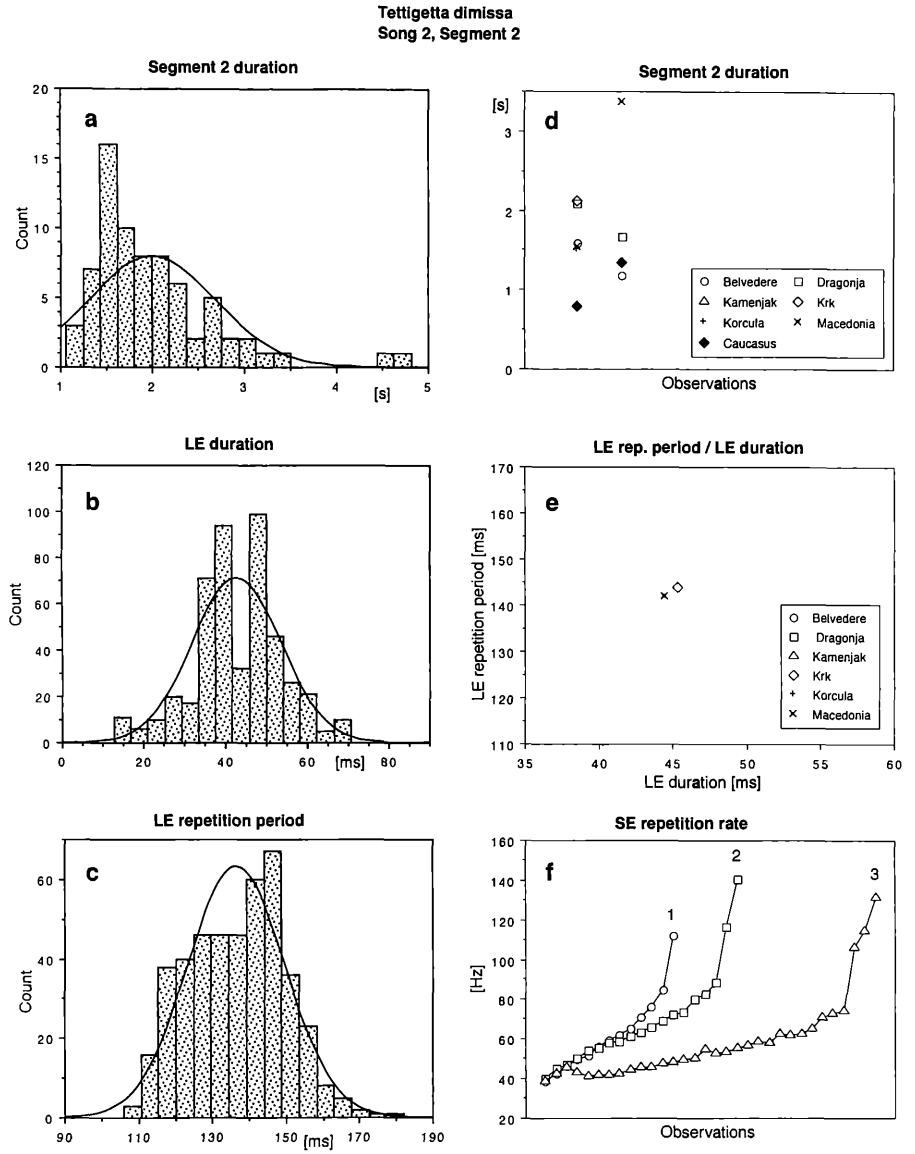

Fig. 6: *Tettigetta dimissa*, time parameters of song type 2, segment 2. a - c, Histograms showing the statistical distribution of data for segment 2; duration (a), long echeme (LE) duration (b), and LE repetition period (c). d - Univariate scattergram of means of segment 2 durations for single animals (N = 18) from different locations; e - scattergram showing relationship between LE repetition period and LE duration in single animals (N = 9) from different regions (for details see legend for Fig. 5); f - plot showing acceleration of SE repetition rate in three subsequent segments 2 of one animal.

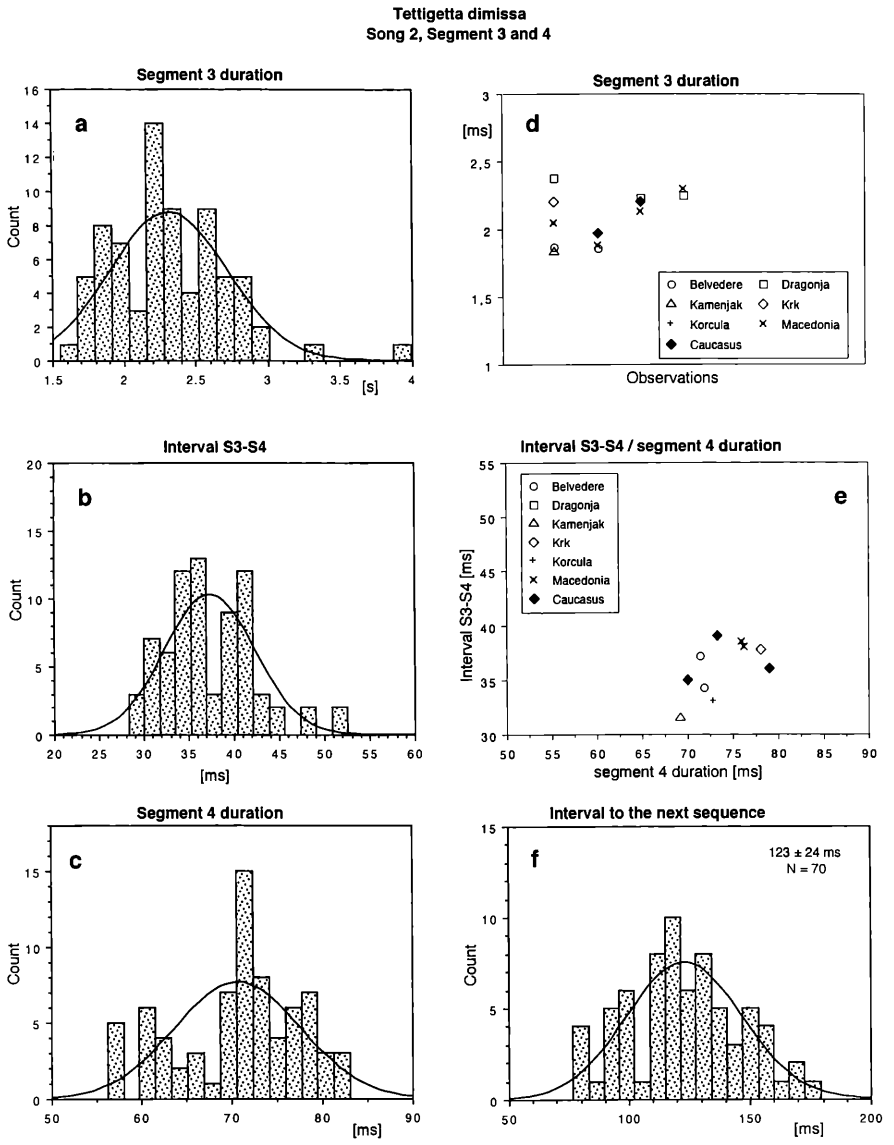

Fig. 7: *Tettigetta dimissa*, time parameters of song type 2, segments 3 and 4. a - c and f, Histograms showing a statistical distribution of data; segment 3 duration (a), interval between segment 3 (S3) and segment 4 (S4) (b), segment 4 duration (c) and interval to the next sequence of song (f). d - Univariate scattergram of means of segment 3 duration for single animals (N = 19) from different locations; e - scattergram showing relation between interval S3-S4 versus segment 4 duration in single animals (N = 19) from different regions (for details see legend for Fig. 5).

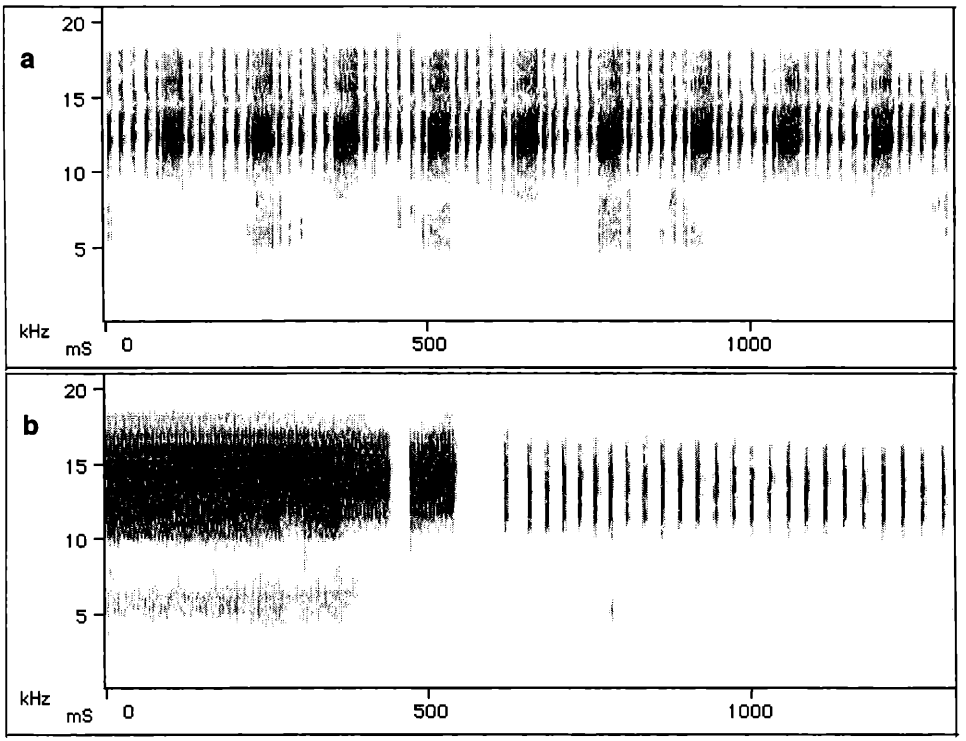

Fig. 8: *Tettigetta dimissa,* sonagrams of a selection of song type 1 (a), and of song type 2 (b) showing part of segment 3, segment 4, and the first part of segment 1 of the next sequence.

References

Boulard M., 1995: Postures de cymbalisation, cymbalisations et cartes d'identité acoustique des cigales. 1.- Généralités et espèces méditerranéennes (Homoptera Cicadoidea). *EPHE, Biol. Evol. Insectes* 7/8, 1994/1995: 1-72.

Fonseca P.J., 1991: Characteristics of the acoustic signals in nine species of cicadas (Homoptera, Cicadidae). *Bioacoustics* 3: 173-182.

Gogala M., Gogala A., 1999: A checklist and provisional atlas of the Cicadoidea fauna of Slovenia (Homoptera: Auchenorrhyncha). *Acta entomologica slovenica*, 7(2): in press.

Gogala M, Popov A.V., Ribarič D., 1996: Bioacoustics of singing cicadas of the western Palaearctic: Cicadetta tibialis (Panzer)(Cicadoidea:Tibicinidae). *Acta entomologica slovenica,* 4(2): 45-62.

Gogala M, Popov A.V., 1997: Bioacoustics of singing cicadas of the western Palaearctic: Cicadetta mediterranea (Panzer)(Cicadoidea:Tibicinidae). *Acta entomologica slovenica,* 5(1): 11-24.

Gogala M., Trilar T., 1998: First record of Cicadatra persica Kirkaldy, 1909 from Macedonia, with description of its song. *Acta entomologica slovenica,* 6(1): 5-15.

Gogala M., Trilar T., 1999: The song structure of Cicadetta montana macedonica Schedl with remarks on songs of related singing cicadas (Hemiptera: Auchenorrhyncha: Cicadomorpha: Tibicinidae). *Reichenbachia Mus. Tierkd. Dresden* 33 (11): 91-97.

Kudryasheva J.V., 1979: Larvae of singing cicadas (Homoptera, Cicadidae) of the fauna SSSR. Nauka, Moskva (in Russian).

Popov, A.V., 1975: The structure of timbals and characteristic of sound signals of singing cicadas (Homoptera, Cicadidae) from the southern regions of the USSR. *Entom. Rev. (Entom. obozrenie),* 54: 258-290.

Popov, A. V., Beganović, A., Gogala, M., 1997: Bioacoustics of singing cicadas of the western Palearctic: Tettigetta brullei (Fieber 1876) (Cicadoidea: Tibicinidae). *Acta entomologica slovenica* 5(2): 89-101.

Schedl, W., 1986: Zur Verbreitung, Biologie und Ökologie der Singzikaden von Istrien und dem angrenzendem Küstenland (Homoptera: Cicadidae und Tibicinidae). *Zool. Jb. Syst.,* 113: 1-27.

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