

Research Article

Calling song structure of *Cicada orni* Linnaeus (Hemiptera: Cicadidae) in Iran: A comparative study with other areas

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Abstract: *Cicada orni* Linnaeus, 1758 is an abundant and common cicada across Europe, North Africa, and western Asia including Iran. The male cicada produces a loud calling song for attraction of females from a long distance. The calling songs are known often to be species-specific and to function in part for species recognition. The present study compares variations in calling song of *C. orni* in Iran with those reported from other areas and also signifies the importance of calling song in species identification. *C. orni* were collected in Mazandaran, Iran during summer 2010. Four features were used: echeme duration, echeme period, interecheme interval, number of echeme/s and dominant frequency. Findings of present study showed some resemblance in time and frequency domains in the calling song among the populations of *C. orni* from Iran and those investigated in Greece, Iberian Peninsula and Turkey. The parameters of calling song showed maximal resemblance with species of Kosmas (Greece). The present results do not support *C. orni* from Iran as an independent subspecies. Thus, it is concluded that every feature of calling song can be effective in species recognition as is the case for several other parameters.

Keywords: *Cicada orni*, Bioacoustic, Calling song, Acoustic divergence, Geographic variation

Introduction

Cicada orni Linnaeus is an abundant and common cicada across Europe, North Africa, and western Asia including Iran (Metcalf, 1963; Dlabola, 1981; Duffels and van der Laan, 1985). The males of *C. orni* produce a loud calling song for attraction of females from a long distance (Bennet-Clark, 1998) by a tymbal mechanism which is located dorsolaterally in the first segment of the abdomen (e. g., Pringle, 1954; Popov, 1975; Bennet-Clark, 1998). The singing male cicada is commonly

observed in shrub lands and woodlands as well as in fruit trees and gardens and also on fences and poles (Popov, 1975; Patterson *et al.*, 1997; Puissant and Sueur, 2001; Sueur *et al.*, 2004). The calling songs are known often to be species-specific and to function partly as species recognition (Lei *et al.*, 1994). The species-specific songs are important in species recognition and in the mating process (Gerhardt and Huber, 2002). Thus, species with different calling songs can be considered as reproductively isolated species and hence as separate species (Gogala and Trilar, 2004). There are important acoustic differences between morphologically similar species such as *Cicadetta* (Puissant and Boulard, 2000, Gogala and Trilar, 2004, Wade *et al.*, 2015) or *Cicada* (Simões *et al.*, 2000, Pinto-Juma *et al.*, 2005). Therefore, acoustic

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characteristic is useful for a better understanding of the speciation process.

Several authors have described the calling songs of *C. orni* (Popov, 1975; Joermann and Schneider, 1987; Boulard, 1995; Claridge *et al.*, 1979; Simões *et al.*, 2000; Quartau *et al.*, 1999; Quartau *et al.*, 2000; Pinto-Juma *et al.*, 2005; Seabra *et al.*, 2006) for a few local populations of this species. However, studies on the acoustic variation across the distribution area of cicadas are rare, with the exception of some work on American cicada (e.g., Moore, 1993). For *C. orni*, introductory comparisons of the calling songs in populations from southern France with those from the former USSR showed no obvious geographic variation (Claridge *et al.*, 1979; Claridge, 1985). Later, Quartau *et al.* (1999), when comparing Portuguese with Greek populations, revealed some geographic variation in *C. orni* songs.

The present paper is an analysis of the structure of the calling songs of *C. orni* in Iran relative to those presented in other papers to evaluate variations of parameters of calling songs.

Materials and Methods

Location and climatic condition

The research was conducted in Babol Mazandaran province of Iran located in the north ($52^{\circ} 41'$ eastern longitude and $36^{\circ} 33'$ northern latitude) during July 2010. The ambient temperature and relative humidity were 28-30 °C and 70-80% respectively during the research.

Collection of specimens

In the natural environment, the calling songs of cicadas were recorded. After recording, cicadas were caught using sweep nets. A total of twelve males were collected.

Sound recording and analysis

Calling songs were recorded by a ZOOM-H4 audio recorder (Sound Laboratory ZOOM, Tokyo, Japan) with internal microphone at a 44 Kb/s sampling rate. It was placed at a distance of a meter from each male in the warmest hours of the day at noon when more cicadas were observed. Each calling song was recorded for ten minutes. The recorded sounds were transferred to an Acer computer, and analyzed by Cool Record Edit Deluxe software (Ver. 7.8.6 Syntrillium Software, Phoenix, AZ, USA) and MATLAB.

To analyze acoustic variables the average values of calling song were calculated: echeme duration, No. of echeme/s, dominant frequency. They were measured with a 0.001s precision on signal oscillograms. Description of acoustic variables is explained in table 1.

Results

The calling song of male of *C. orni* continues for a very long time. Calling songs of *C. orni* is regular repetition of echemes with 0.116 ± 0.107 (average \pm standard deviation) seconds and interecheme interval of 0.093 ± 0.037 seconds (Fig.1b), which constitute groups of impulses (Fig.1c). The spectral characteristics of the signal showed a peak frequency of 4.24 kHz (Fig.2). The frequency range is 4.45 ± 0.2 kHz. Table 2 shows the time and spectral characteristics of the male cicada's calling songs.

Mean acoustic values of specimens from Iran and other areas have slight intraspecific variations. Moreover, the species of *C. orni* do not appear to be isolated, but perhaps overlapping instead.

Table 1 Descriptions of the calling song variables analyzed in *Cicada orni*.

Variable	Description
echeme	Each phrase consist of echemes, uninterrupted sequences of sound pulses (see Broughton, 1976)
Echeme duration	Duration of each echeme from start to end (Pinto-Juma <i>et al.</i> , 2005)
Interecheme interval	Interval between the end of an echeme and beginning of the next echeme (Pinto-Juma <i>et al.</i> , 2005)
Echeme period	Duration between the start of one echeme and the beginning of the following one (Pinto-Juma <i>et al.</i> , 2005)
Dominant frequency	The frequency of the maximum amplitude on the spectrogram (Pinto-Juma <i>et al.</i> , 2005)

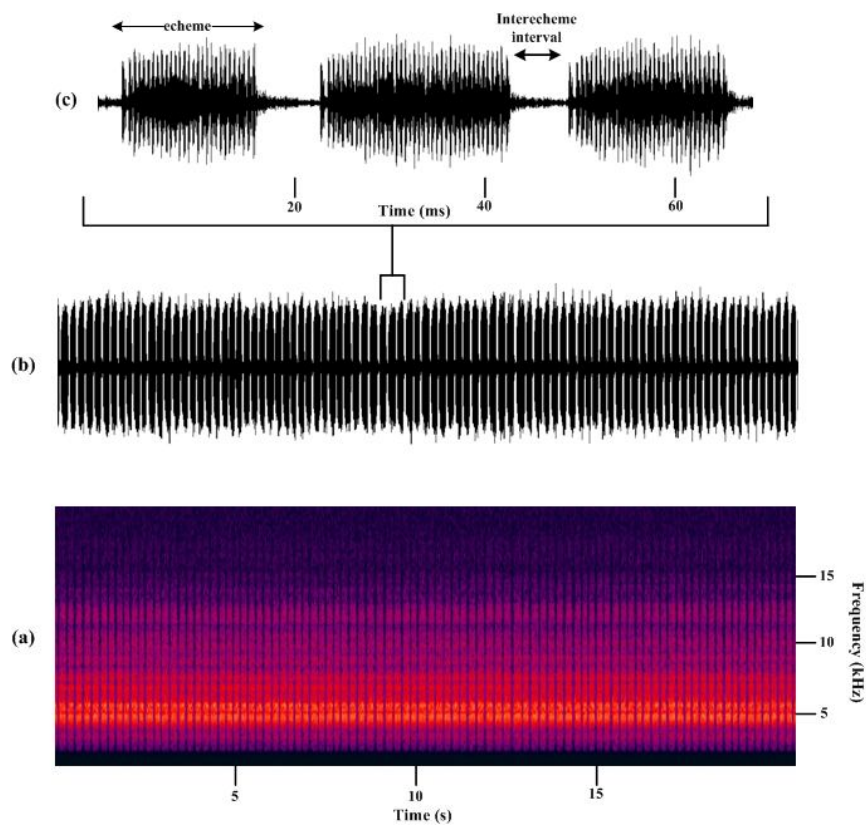


Figure 1 Calling song of *Cicada orni*; a: spectrogram of the calling song; b: oscillogram of the calling song which consists of regular repetition of echemes and interecheme intervals; c: echemes and interecheme intervals.

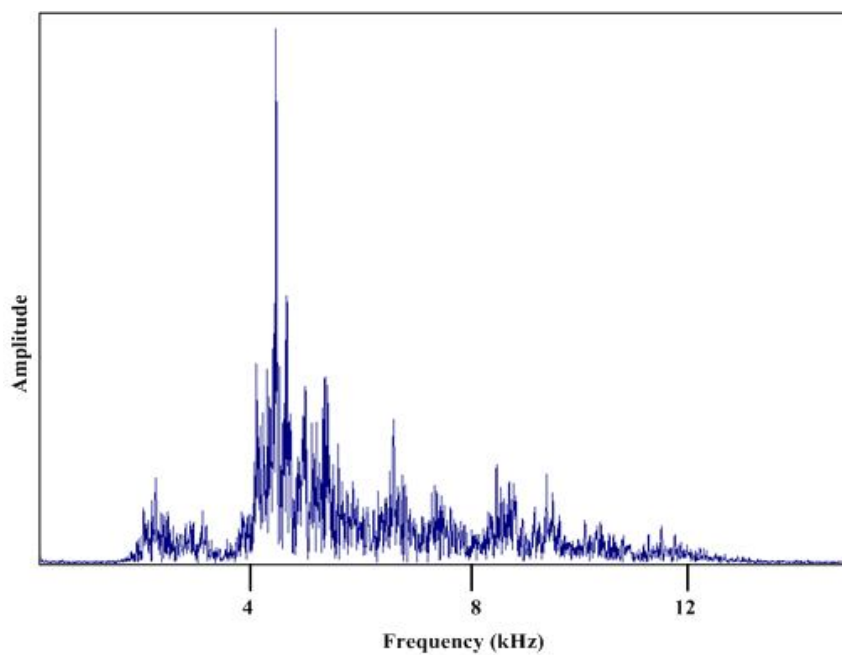


Figure 2 Example of a spectrum of the calling song of *Cicada orni* male with the peak frequency near the 4.45 kHz.

Discussion

Several authors (Popov, 1975; Joermann and Schneider, 1987; Fonseca, 1991; Boulard, 1995; Claridge *et al.*, 1979; Simões *et al.*, 2000; Simões *et al.*, 2006; Quartau *et al.*, 1999; Quartau *et al.*, 2000, Quartau and Simões, 2005; Pinto-Juma *et al.*, 2005, Seabra *et al.*, 2006; Sueur *et al.*, 2010; Zeybekoğlu *et al.*, 2011) described calling songs of *C. orni* as a pattern of regular repetition of echemes and interecheme intervals.

Our acoustic results in time and frequency domains reveal some resemblance in the calling song among the populations of *C. orni* investigated in Greece, Iberian Peninsula and Turkey (Table 3), the parameters of calling song are most similar to specimens of Kosmas (Greece). Echeme duration, interecheme interval and no. of echemes/s for specimens of Kosmas are 0.15s, 0.09s and 4.28, respectively

(Simões *et al.*, 2006). And also some parameters such as interecheme intervals of our data are almost equal with those of *C. orni* inhabiting Turkey with mean of 0.084 s in Tosya and 0.092 s in Ispir (Zeybekoğlu *et al.*, 2011) and also specimens of Lesbos in Greece (mean of 0.09s) (Simões *et al.*, 2006). The parameter of echeme period is the same as specimens of Andros in Greece (mean 0.20s) (Simões *et al.*, 2006). Dominant frequency is almost the same in mentioned areas (Table 3). Therefore, the present results do not support *C. orni* from Iran as an independent subspecies. For *C. orni*, introductory comparisons of the calling songs in populations from southern France with those from the former USSR showed no obvious geographic variation (Claridge *et al.*, 1979, Claridge, 1985). Quartau *et al.* (1999), and when compared the Portuguese with Greek populations, revealed some geographic variation in *C. orni* songs.

Table 2 Calling song variation for *Cicada orni* males.

Variable	N	Mean	Std. Deviation	Maximum	Minimum
Echeme duration (s)	301	0.116	0.107	1.464	0.043
Interecheme interval (s)	296	0.093	0.038	0.325	0.021
Echeme period (s)	265	0.209	0.690	0.110	1.020
No. echeme/s	84	5.053	0.843	6.5	1.5
Dominant frequency (kHz)	190	4.450	0.200	5	4

N: Sample size.

Table 3 Descriptive analysis of parameters of calling song of *Cicada orni* in different area.

Country	Greece			Turkey			
	Kosmas	Lesbos	Andros	Dionysos	Tosya	Ispir	Iberian Peninsula
Authors	Simões <i>et al.</i> (2006)	Simões <i>et al.</i> (2006)	Simões <i>et al.</i> (2006)	Simões <i>et al.</i> (2006)	Zeybekoğlu <i>et al.</i> (2011)	Zeybekoğlu <i>et al.</i> (2011)	Seabra <i>et al.</i> (2006)
Echeme duration	0.15*	0.09	0.06	0.09 ± 0.03*	0.06 ± 0.02	0.07 ± 0.01	0.07 ± 0.03
Interecheme intervals	0.09*	0.09*	0.14	0.25 ± 0.10	0.08 ± 0.02*	0.09±0.02*	0.12 ± 0.07
Echeme period	0.24*	0.18*	0.20*				0.20 ± 0.06*
No. echeme/s	4.28	5.60	5.25*	2.92 ± 0.66			5.37 ± 1.33*
Dominant frequency	4.65*	4.47*	4.58*	4.78 ± 0.54*			4.70 ± 0.45*

*: Resemblance features of calling song with Iran.

Pinto-Juma *et al.*, (2005) observed echeme duration of *C. orni* which proved to be quite constant across the geographic range of this cicada. But conversely data of Pinto-Juma *et al.* (2005) that described the interecheme interval was quite variable, and so it is expected that this variable is not an important parameter for species recognition and isolation in *C. orni*. According to our data, interecheme intervals were equal in Iran, same as in Greece and Turkey (Simões *et al.*, 2006; Zeybekoğlu *et al.*, 2011). Thus, we assume that inter-echeme interval is effective in species recognition like other song parameters.

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تجزیه و تحلیل صدای فراخوانی زنجره *Cicada orni* Linnaeus در ایران: مقایسه صوتی با مناطق دیگر

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چکیده: زنجره *Cicada orni* Linnaeus, 1758، گونه‌ای فراوان و معمول در اروپا، شمال آفریقا، غرب آسیا از جمله ایران است. زنجره‌های نر برای جلب ماده از فاصله‌های دور، صدای فراخوانی تولید می‌کنند. صدای فراخوانی به‌عنوان ویژگی مخصوص گونه‌ها شناخته شده است که برای شناسایی گونه‌ها مورد استفاده قرار می‌گیرد. مقاله حاضر تفاوت در صدای فراخوانی *C. orni* در ایران و مناطق دیگر را نشان می‌دهد و همچنین اهمیت صدای فراخوانی در تشخیص گونه را بیان می‌کند. زنجره *C. orni* در مازندران در تابستان ۱۳۸۹ جمع‌آوری شده است. چهار ویژگی صدای فراخوانی شامل مدت اجم، دوره اجم، فاصله زمانی بین اجم‌ها، تعداد اجم‌ها در ثانیه و فرکانس پایه محاسبه شده است. نتایج نشان دهنده شباهت محدوده‌ی زمانی و فرکانسی صدای فراخوانی در مناطق یونان، ایبریا پنسیلوانیا و ترکیه است. پارامترهای صدای فراخوانی شباهت بیش‌تری با گونه‌ی منطقه کسماس در یونان نشان می‌دهد. بررسی صدای فراخوانی مناطق مختلف با ایران، اهمیت گونه فوق را به‌عنوان یک گونه، نه زیرگونه نشان می‌دهند. لذا نشان‌دهنده این است که هر ویژگی صدای فراخوانی، همانند سایر پارامترها می‌تواند در تشخیص گونه مؤثر باشد.

واژگان کلیدی: *Cicada orni*، صدای فراخوانی، بیواکوستیک، تفاوت صوتی، تنوع جغرافیایی