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A DESCRIPTION OF THE MALE DRUMMING CALL OF *BESDOLUS VENTRALIS* (PICTET, 1841) (PLECOPTERA: PERLODIDAE)

Kirill Márk Orci[1]*, Tibor Kovács[2] and Dávid Murányi[3]

[1]*MTA-ELTE-MTM Ecology Research Group, a joint research group of the Hungarian Academy of Sciences, Eötvös Loránd University and the Hungarian Natural History Museum*
H-1088 Budapest, Baross u. 13, Hungary
E-mail: orci.kirill.mark@nhmus.hu; https://orcid.org/0000-0002-4076-6700
[2]*Mátra Museum of the Hungarian Natural History Museum*
H-3200 Gyöngyös, Kossuth L. u. 40, Hungary
E-mail: koati1965@gmail.com; https://orcid.org/0000-0003-4577-0394
[3]*Department of Zoology, Eszterházy Károly Catholic University*
H-3300 Eger, Leányka út 6, Hungary, E-mail: d.muranyi@gmail.com
https://orcid.org/0000-0002-3907-5590

This paper gives the first description of the male drumming call of *Besdolus ventralis*. Based on the examination of a single male specimen of this rare stonefly species, its male call is composed of 3 beat groups, each containing 3–6 beats repeated at decreasing inter-beat intervals. Beat groups are separated by 184–212 ms intergroup intervals. Call duration varied between 496–549 ms at ambient air temperature 18.7–20.4 °C. These results show that the male call of *B. ventralis* is clearly different from the diphasic call of *B. ravizzarum*, and is rather similar to that of *B. bicolor*, which is the closest relative of *B. ventralis* according to mitochondrial DNA sequences. The main difference between the male calls of the two species seems to be that *B. ventralis* produces 3–6 beats per group, while *B. bicolor* is reported to produce only 2 (rarely 3) beats per beat group.

Key words: Plecoptera, vibrational communication, drumming call, oscillogram.

INTRODUCTION

Vibrational communication is an essential element of the mate finding behaviour of many species of stoneflies (Steward & Sandberg 2006). Males searching for females produce vibrational signals (male call) to get in contact with females that respond to the distant, calling males with their own vibrational signal (female answer), helping the male find her. Those signals are produced most frequently by drumming: hitting the substrate with the caudal end of their abdomen. The rhythmic pattern of male calls proved to be species-specific in most studied species (e.g. Rupprecht 1969, Bottorff *et al.* 1990, Tierno de Figueroa *et al.* 2002, Graf *et al.* 2014). Experimental studies examining female preference also suggest that inter-sexual vibrational signalling is likely to be an important element of the species-specific mate recognition system of these insects (Rupprecht 1982, Zeigler & Stewart 1986,

Stewart & Maketon 1990, Boumans & Johnsen 2014, Orci & Murányi 2021). Therefore, studying the oscillographic pattern of those signals may help us resolve species-level taxonomic problems and reveal a hidden diversity of the biology of these insects (Tierno de Figueroa *et al.* 2011, Murányi *et al.* 2014).

From the five presently known species of the genus *Besdolus* Ricker, 1952, detailed descriptions of the male calls are available only in two species: *B. bicolor* (Navás, 1909) (Tierno de Figueroa *et al.* 2013) and *B. ravizzarum* Zwick et Weinzierl, 1995 (Ruffoni & Tierno de Figueroa 2019). Furthermore, Ruppreccht (2014) presented results about the drumming signals of *B. imhoffi* (Pictet, 1841) at the 1st European Plecoptera Symposium, but his study has not been published, unfortunately. In this paper, we describe the male call of *B. ventralis*. Since our study is based on 3 calls recorded from a single specimen, the description presented here has to be regarded as preliminary. *Besdolus ventralis* is a rare stonefly species, which is known to occur only in the Lafnitz-Rába river system (Austria, Hungary) (Kovács & Ambrus 2001, Kovács *et al.* 2004) and in the river Aliakmonas (Greece) (Kovács & Murányi 2008). Specimens are very difficult to collect, and considering the taxonomic importance of the call pattern, we decided to write this short report about the structure of the drumming call produced by the examined specimen.

MATERIAL AND METHODS

The examined male was collected by T. Kovács and D. Murányi in Greece from the Aliakmonas river, NE of the city of Neapoli (N40°19.976′, E21°24.678′), 555 m a. s. l., 08.05.2014.

The examined male specimen was placed on the diaphragm of a dynamic speaker (covered by a transparent plastic sheet to prevent the animal from escaping) to record its drumming calls. The vibrations of the diaphragm produced by the signalling animal made the conus of the speaker move, inducing voltage fluctuations recorded by a Zoom H4n recorder. The age of the examined male was unknown to us since the specimen was collected as an adult. The male was recorded on two consecutive days (14. and 15.05.2014.), and two types of speakers were used as electrical transducers: a SAL YD78 speaker on 14th, and an Orion LB 1031 on 15th. The specimen was left undisturbed during the recording sessions, and its spontaneous signalling was recorded. The ambient air temperature was measured during each recording using a P 300W thermometer (Dostmann Electronic GmbH).

Recorded male calls were analysed using the software Adobe Audition 1.5 (San Jose, CA, USA). Vibrational signal characters were measured manually on the oscillograms of unfiltered recordings. Low amplitude beats at the end of each beat group were identified by listening to the 6400% (64×) time expanded versions of the original recordings. Inter-beat intervals were measured between the peaks of consecutive beats. Inter-beat group intervals were measured from the peak of the last beat of the preceding beat group to the peak of the first beat of the following beat group. Oscillograms presented in this paper were produced using the package seewave 2.1.4 (Sueur *et al.* 2008) running under R 3.6.1 (R Core Team 2019).

RESULTS

Oscillographic structure of the male call of *Besdolus ventralis* – The following description is based on three calls of one male specimen of *Besdolus ventralis*. Each of the recorded three calls was composed of three beat groups (Fig. 1A). Beat groups consisted of 3–6 beats (Fig. 1B–D). In each beat group, beats were repeated with decreasing inter-beat intervals, and the first two beats had much higher amplitude than the following, low-amplitude ones. For inter-beat intervals, number of beats per group and inter-group intervals, see Table 1. Call duration varied between 496–549 ms. Calls were recorded at ambient air temperatures 18.7 (call 1) and 20.4 (call 2–3) °C.

DISCUSSION

The male drumming calls of the examined *Besdolus ventralis* specimen consisted of 3 beat groups, and each beat group contained 3-6 beats repeated

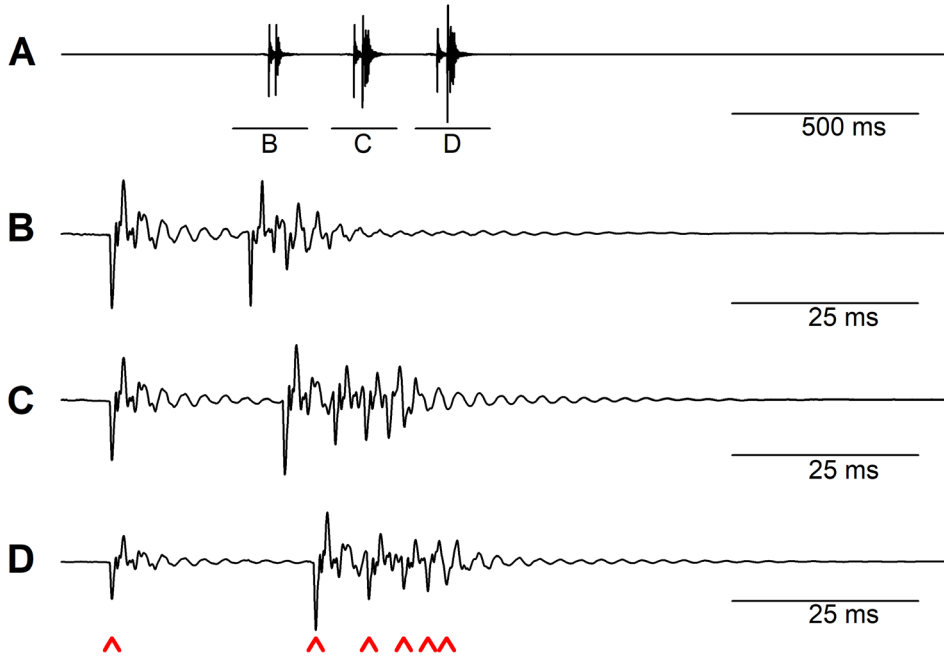

Fig. 1. Oscillograms at different time resolutions showing the amplitude modulation pattern of a *Besdolus ventralis* male call. A, an entire call; B, the first beat group of the call shown in A; C, the second beat group of the call shown in A; D, the third beat group of the call shown in A, red /\ symbols point toward individual beats. (Amplitude is normalised to 100% in each oscillogram.)

Table 1. Measurement data for some rhythmic characters of the male drumming call of *Besdolus ventralis*. Abbreviations: ix is the xth inter-beat interval of a given beat group counted from the beginning of the group, N of beats is the number of beats observable in the given beat group. Call1 was recorded at 20.4, calls 2 and 3 were recorded at 18.7 °C. All duration values are given in milliseconds. NA means not available.

	i1	i2	i3	i4	i5	N of beats	Duration of group	Inter-group interval
Beat group I								
call1	18	4	NA	NA	NA	3	22	206
call2	20	6	3	NA	NA	4	29	212
call3	20	7	4	5	NA	5	36	211
Beat group II								
call1	23	6	4	3	2	6	38	184
call2	24	8	5	3	2	6	42	201
call3	25	8	5	4	5	6	47	201
Beat group III								
call1	27	7	4	3	2	6	43	NA
call2	27	8	5	3	2	6	45	NA
call3	26	8	5	3	4	6	46	NA

with decreasing inter-beat intervals. Based on these features, the male call of this species can be categorised as a grouped call showing varied beat interval patterns within each group using the stonefly drumming signal terminology proposed by Sandberg *et al.* (2015).

Besdolus ventralis is the third species in the genus to which we now have detailed information about the oscillographic pattern of the male call. It is clearly different from the diphasic signal pattern reported for *B. ravizzarum* (Ruffoni & Tierno de Figueroa 2019), but very similar to the calls described for *B. bicolor* (Tierno de Figueroa *et al.* 2013). The main difference between the male calls of the latter two species seems to be that *B. ventralis* produces 3–6 beats per group, while *B. bicolor* is reported to produce only 2 (rarely 3) beats per beat group. However, that difference cannot be seen in low time-resolution oscillograms that show only the two initial, high amplitude beats of each group (Fig. 1A). The similarity of the male call of the two species is in accordance with their close phylogenetic relationship suggested by molecular genetic results based on the examination of a mitochondrial marker (Fochetti *et al.* 2011). In order to clarify the relationship of the two taxa, it will be essential to record the male-female duet in both species since the timing and pattern of the female answer may also vary between closely related species (Rupprecht 1997), and this can be of critical importance regarding reproductive isolation. Further studies will be needed to reveal the intra-specific variation of the male

call of *B. ventralis*, not only by examining more specimens, but especially to compare the signals of the two populations occurring in the Raba-Lafnitz river system (Austria, Hungary) and the Aliakmonas river (Greece).

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