Russian Entomol. J. 31(4): 346–351

Male calling signals of *Sphingonotus obscuratus latissimus* (Uvarov, 1925) (Orthoptera: Acrididae: Oedipodinae) from the population near the type locality in southeastern Kazakhstan

Призывные сигналы самцов *Sphingonotus obscuratus latissimus* (Uvarov, 1925) (Orthoptera: Acrididae: Oedipodinae) из популяции близ типового местонахождения в юго-восточном Казахстане

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KEY WORDS: grasshopper, Acrididae, Oedipodinae, *Sphingonotus obscuratus latissimus*, calling signal, flight display, acoustic communication.

КЛЮЧЕВЫЕ СЛОВА: саранчовые, Acrididae, Oedipodinae, *Sphingonotus obscuratus latissimus*, призывный сигнал, демонстрационный полёт, акустическая коммуникация.

ABSTRACT. The calling signals of males of *Sphingonotus obscuratus latissimus* from the vicinity of the type locality in southeastern Kazakhstan were studied. The signal consists of a sequence of syllables produced during flight and one or several syllables produced by tegmino-femoral stridulation immediately after landing. The reasons for the convergent emergence of signals produced during flight in different taxa of Oedipodinae are discussed.

РЕЗЮМЕ. Исследованы призывные сигналы самцов *Sphingonotus obscuratus latissimus* из окрестностей типового местонахождения в юго-восточном Казахстане. Сигналы состоят из последовательности пульсов, издаваемых при помощи крыльев во время демонстрационного полёта, и одного или нескольких пульсов, продуцируемых при помощи тегмино-феморальной стридуляции сразу после приземления. Обсуждаются предпосылки конвергентного возникновения издаваемых в полёте сигналов в разных таксонах Oedipodinae.

Introduction

In the subfamily Oedipodinae (Orthoptera: Acrididae), acoustic communication is poorly developed. Most members of this subfamily have bright-colored hindwings and/or hind legs and, apparently, use visual cues during the search of conspecific mate and the competitive behavior. Only after establishing visual contact, being at a distance of no more than 20–30 cm from each other, individuals can produce stridulatory signals by means of the tegmino-femoral mechanism.

For example, in two Mediterranean species of *Sphingonotus*, the chorus songs produced by males during competitive behavior were described. Also, a courtship song was recorded in one of these species; in the second species courtship behavior was not observed [García et al., 1997]. The signals of the same two types were registered in *S. octofasciatus* (Serville, 1839) [García et al., 2001] and in two species from other genera of Oedipodinae [Larrosa et al., 2010]. Songs of *S. caerulans caerulans* Werner, 1908 and *S. rubescens* (Walker, 1870) from the Canary Islands were described by Husemann and Hochkirch [2007]. Stridulation in several species of Oedipodinae was described by Savitsky and Lekarev [2007], but signal oscillograms are given only for four species. Description of precopulatory signals of *Sphingonotus* (*Sphingonotus*) *coerulipes djakonovi* Mishchenko, 1936 is given in Benediktov [2009].

Only in *Stethophyma grossum* (Linnaeus, 1758) single male produce calling signals by means of the tibio-tegminal mechanism while sitting on the plant. The receptive female produce response signals and, as a result, the mates find each other [Ragge, Reynolds, 1998; Savitsky, Lekarev, 2007]. Thus, the communication system of *S. grossum* is similar to that of Gomphocerinae; still, both morphological and recent molecular

How to cite this article: Tishechkin D.Yu. 2022. Male calling signals of *Sphingonotus obscuratus latissimus* (Uvarov, 1925) (Orthoptera: Acrididae: Oedipodinae) from the population near the type locality in southeastern Kazakhstan // Russian Entomol. J. Vol.31. No.4. P.346–351. doi: 10.15298/rusentj.31.4.02

studies confirm that this species belongs to Oedipodinae [Fries et al., 2007].

Also, some Oedipodinae species produce sounds by wings during so-called flight displays.

Oscillograms and brief descriptions of signals of *Helioscirtus moseri* Saussure, 1884, two species of *Bryodema* Fieber, 1853, and *Sphingonotus obscuratus latissimus* (Uvarov, 1925) were published by Xi et al. [1992]. This is the first known to us investigation of grasshopper signals emitted during the flight, made using electronic equipment, and it is of great interest, although signal descriptions are not informative enough.

Wing crepitation during flight in *Psophus stridulus* (Linnaeus, 1758), a species common throughout Europe, has long been known. We find it difficult to name the first work where its signals were described; we can only point out that the oscillograms of signals of this species are given in Ragge and Reynolds [1998].

Signals produced by wings during flight displays were also described in five species of the tribe Bryodemini [Xi et al., 1992; Benediktov, 1998; Savitsky, Lekarev, 2007; Tishechkin, 2010]. As a rule, flight display lasts much longer than a usual flight of a disturbed insect; also, in most species, males fly in an undulating trajectory, moving up and down in the rhythm of producing syllables.

In *Hyalorrhipis clausi* (Kittary, 1849), the calling signal is more complex. When producing its main part, the male periodically jumps a few centimeters and makes a crackling sound with its wings. Then he begins to alternate syllables emitted by the wings with syllables emitted by stridulation and short pulses emitted by the tibio-tegminal mechanism. Thus, the same signal is produced in three different ways (wing crepitation, stridulation, and the tibio-tegminal mechanism). Remarkably, the male produces wing crepitation while in the air, and the other two components while sitting on the ground [Savitsky, Lekarev, 2007].

Also, some authors indicate that a number of other species of Oedipodinae are capable of emitting signals during flight, but they do not provide further details or signal descriptions. Shumakov [1963: 150] points out that many species of Sphingonotini produce wing crepitation while flying. In the same work, when writing about *Sphingonotus savignyi* Saussure, 1884 and *S. paradoxus* Bey-Bienko, 1948, he notes that “Both species stridulate on the fly” [Shumakov, 1963: 159]. The ability to make sounds in flight has also been noted in *Sphingonotus rubescens* [Bland, 1985].

The fact that *Sphingonotus obscuratus latissimus* produces sounds during the flight was first pointed out by Bey-Bienko and Mishchenko [1951: 632]. Later, some other authors [Lachininskiy et al., 2002: 303; Childebaev, Storozhenko, 2001] mentioned the same fact, apparently, following Bey-Bienko and Mishchenko [1951].

First recordings of signals of this species were made by Xi et al. [1992] in Fuhai County, Xinjiang Uygur Autonomous Region, China. However, as was mentioned above, too brief signal description illustrated by oscillograms at one speed is insufficiently informative.

In the present paper, illustrated description of signals of *S. obscuratus latissimus* from the environs of the type locality is given and considerations concerning the convergent emergence of signals produced by wings during flight in different taxa of Oedipodinae are provided.

Material and methods

Observations and material collection were made on 13 June 2022 in the rocky desert between the Ili River and the lower Charyn River, southeastern Kazakhstan, in the localities about 4 km and 12 km west of the Charyn River (N 43.717°, E 79.359° and N 43.735°, E 79.268°, respectively). Signal recordings were made in the locality 12 km west of the Charyn River (Fig. 1) at the shadow air temperature 38°C.

Grasshopper sounds were recorded from freely-flying insects under field conditions by means of Roland R-05 wave/mp3 recorder at the sampling frequency 96 kHz. Oscillograms and spectrograms of signals were produced with Cool Edit Pro 2.1 software.

According to the terminology of grasshopper signal elements [Ragge, Reynolds, 1998], **syllable** is a sound produced by one complete up- and downstroke of a grasshopper hind leg. In this paper, we also use the same term for a short discrete sound produced by wings during flight.

Specimens studied are deposited in the collection of the Zoological Museum of M.V. Lomonosov Moscow State University.

Results

According to Zubovskiy [1898] and Uvarov [1925], the type specimens of *S. obscuratus latissimus* were collected near the Iliyskiy village (at present, in its place is the Kapchagay reservoir) and near Chundzha town, about 25 km southeast of localities where our material was collected. However, the label under the type specimen presented on the photograph on the Orthoptera Species File Online website [Cigliano et al.; http://orthoptera.speciesfile.org/Common/basic/ShowImage.aspx?TaxonNameID=1103875& ImageID=241010] states: “Semirechensk region, the Charyn river valley” without any other data. Since this species inhabits only rocky deserts and cannot live on the river bank or in irrigated lands in the river valley, apparently, the places where our studies were carried out are within the type locality or in its immediate vicinity.

Singing males of *S. obscuratus latissimus* concentrated on areas completely devoid of vegetation (Fig. 1). Several males sitting next to each other performed flight displays in turn, so that the signals of different individuals followed one after another (Figs 4–5). The singing male usually landed on a rocky place, avoiding even sparse vegetation (Fig. 2).

According to Bey-Bienko and Mishchenko [1951], the male produces a soft crepitation when flying; in fact, the sounds are quite loud and well audible to the human ear at a distance of at least 10 m. In addition, the flying male is clearly visible due to the contrastingly colored hindwings (Fig. 3).

Unlike the singing Bryodemini males, which can fly continuously for several minutes, the flight displays of *S. obscuratus latissimus* last for about of 1.5–3.0 s. In general, the flight path of the male more or less is an arc; during flight, it does not perform the periodic up and down movements characteristic of most Bryodemini. Immediately after landing, male usually (but not always) produce one or several syllables by tegmino-femoral stridulation. The syllables produced during the flight and on the ground differ in frequency spectra, due to which they are clearly distinguishable on the sonogram (Figs 6–11). In the part of signal produced during flight, syllable repetition period averages 44–50 ms in our recordings. Duration of a gap between the end of the flight and the syllable produced by tegmino-femoral stridulation varies from 130 up to 600 ms in our recordings. If the male produces two or more syllables, their repetition period ranges from 150 up to 650 ms.

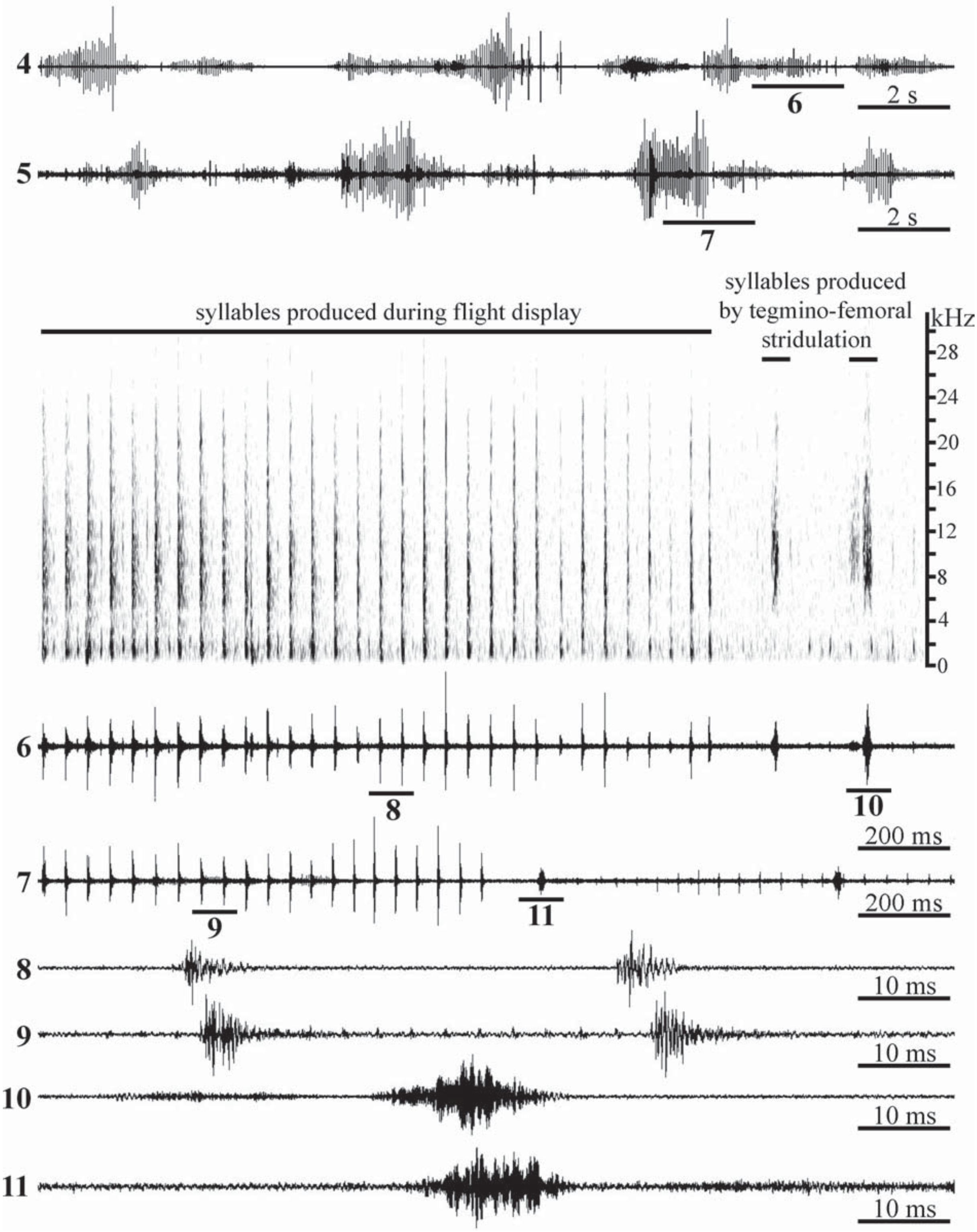
1

2

3

Figs 1–3. *Sphingonotus obscuratus latissimus*: 1 — habitat in the environs of the type locality in southeastern Kazakhstan; singing males concentrated on a rocky place in the middle part of the photo; 2 — same locality, male after flight display; 3 — dry male specimen from the environs of the type locality.

Рис. 1–3. *Sphingonotus obscuratus latissimus*: 1 — местообитание в окрестностях типового местонахождения в юго-восточном Казахстане; поющие самцы концентрировались на каменистом участке в средней части фото; 2 — там же, самец после демонстрационного полёта; 3 — самец из окрестностей типового местонахождения.



Figs 4–11. Male calling signals of *Sphingonotus obscuratus latissimus* from the environs of the type locality in southeastern Kazakhstan: 4–5, 7–11 — oscillograms; 6 — sonogram and oscillogram at the same speed. Faster oscillograms of the parts of signals indicated as “6–11” are given under the same numbers.

Рис. 4–11. Призывные сигналы самцов *Sphingonotus obscuratus latissimus* из окрестностей типового местонахождения в юго-восточном Казахстане: 4–5, 7–11 — осциллограммы; 6 — сонограмма и осциллограмма при одной скорости развертки. Фрагменты сигналов, помеченные цифрами “6–11”, представлены при большей скорости развёртки на осциллограммах под соответствующими номерами.

Discussion

The signals studied by us are generally similar to those of *S. obscuratus latissimus* from Western China, although the signals of males from China are somewhat shorter [Xi et al., 1992].

The producing of a single signal by means of two or more different sound apparatuses is a rather rare phenomenon in Orthoptera. However, a similar case is known in *H. clausi* [Savitsky, Lekarev, 2007]. Moreover, apparently, all Oedipodinae that produce signals during flight are capable of stridulation on the ground as well [Benediktov, 1998, 2006]. Therefore, the combination of elements produced by two different sound apparatuses in the same signal does not require morphological adaptations and, quite likely, will be found in other species of Oedipodinae.

Calling signal of *S. obscuratus latissimus* is similar to this of *Bryodema gebleri* (Fischer von Waldheim, 1836). Syllable successions produced by the wings in these species are almost indistinguishable, since syllable repetition period in *S. obscuratus latissimus* averages 44–50 ms *vs* 50–70 ms in *B. gebleri* [Benediktov, 1998; Savitskiy, Lekarev, 2007]. *B. gebleri* does not stridulate on the ground after the end of the flight, but this difference can hardly play a significant role, since such syllables are also sometimes absent in the signal of *S. obscuratus latissimus*. Apparently, these species can contact each other; for example, in Mongolia they were found in the same locality [Dey et al., 2021]. A similar situation is observed in *Bryodema luctuosum* (Stoll, 1813) and *Bryodemella holdereri* (Krauss, 1901), which also sometimes inhabit the same biotope and in which the syllable repetition periods also overlap [Tishechkin, 2010]. Evidently, in both cases, insects use not only acoustic, but also visual cues for recognition of a conspecific mate, since these species differ from each other in the hindwing coloration.

Sound producing during flight in species from different tribes, namely, in Bryodemini (*Bryodema*, *Angaracris* Bey-Bienko, 1930), Sphingonotini (*Sphingonotus* Fieber, 1852, *H. clausi*), and Locustini (*P. stridulus*), apparently, has a convergent nature. This assumption is confirmed by the fact that in some taxa of Oedipodinae, convergence of wing morphology was revealed [Husemann et al., 2010].

Many grasshopper species occasionally produce low-amplitude signals when flying. They can emit such signals both during spontaneous flights and when flying from place to place when disturbed. Such sounds were registered in *Acrida* Linnaeus, 1758 [Savitskiy, Lekarev, 2007; Benediktov, 2008], *Sphingonotus rubescens* (Walker, 1870) [Bland, 1985], *Oedaleus decorus* (Germar, 1817), *Pyrgodera armata* Fischer-Waldheim, 1846, *Leptopternis gracilis* (Eversmann, 1848) [Savitskiy, Lekarev, 2007], and in some other species. The function of these sounds is unclear; quite possible that they are simply a side effect of the wing movements. In particular, we repeatedly heard such sounds during the flight of *Stauroderus scalaris* (Fischer-Waldheim, 1846), which uses elaborate species-specific signals produced by stridulation for intraspecific communication. Apparently, only small changes in the wing morphology (for example, thickening of some veins) are necessary in order for the sound emitted during flight to become louder and could be used as a communication signal. Probably, this is the reason for the repeated independent emergence of flight displays accompanied by sounds in unrelated species of Oedipodinae.

Acknowledgements. I am most grateful to my friend Asek Abdykulov (Kyrgyzstan, Kara-Balty) for invaluable help during the expedition to southeastern Kazakhstan. The reported study was carried out as a part of the Scientific Project of the State Order of the Government of Russian Federation to Lomonosov Moscow State University No. 121032300063-3.

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