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Studies of Vibratory Signals in Pentatomid Bugs (Heteroptera, Asopinae) from European Russia

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Abstract—The vibratory signals of four species of Asopinae (Pentatomidae) from European Russia are described for the first time. The signals emitted by adult bugs are classified into three types: male rivalry signals, male calling signals, and solitary low-amplitude signals with still unknown function. The latter are similar in different species and show no species-specific features. Oscillograms and sonograms of vibratory signals are given for all the species studied.

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Vibratory communication is known in a number of representatives of the order Heteroptera. The main organs involved in this communication in the studied pentatomid bugs are the tergal tymbals (Gogala, 1985), emitting low-frequency vibratory signals with a fundamental frequency of 100 to 120 Hz and distinct frequency modulation. In addition, vibratory signals can also be produced by stridulation (for example, of tibial and sternal spinules, resulting in signals of a higher frequency within the range of 1–5 kHz), and by the wing musculature (McDonald, 1979; Gogala, 1984; Čokl and Virant-Dobelret, 2003). According to the published data, the signals of members of the family Pentatomidae usually have several frequency peaks within a range of 100–800 Hz, which appears to be related to the mechanical properties of the plants as a substrate in which the vibratory signals propagate. The low frequency signals have been shown to travel the greatest distances over the plant (Michelsen et al., 1982). No previous bioacoustic studies of heteropterans have been carried out in Russia.

Vibratory communication in Pentatomidae has been mostly studied in several species from the subfamily Pentatominae, uniting plant pests with generally low activity. In particular, members of the genus *Palomena* revealed several functional types of signals: courtship, rivalry, and calling (Čokl et al., 1978). Contrariwise, bugs of the subfamily Asopinae are active predators, feeding mostly on leaf beetles (Coleoptera, Chrysomelidae). Brief preliminary descriptions of the signals emitted by *Picromerus bidens* L. and *Podisus maculiventris* Say were published in the review by M. Gogala (2006). At the same time, a study of the communication system and signal structure of these insects holds much promise not only from the taxonomic viewpoint, but also with respect to their possible use as biological pest control agents.

The subfamily Asopinae is represented in European Russia by eight species, of which three (*Picromerus bidens*, *Troilus luridus* F., and *Zicrona caerulea* L.) are common.

The aims of this work were to study the vibratory repertoire of bugs of the subfamily Asopinae, to characterize the function of the signals, and to estimate the degree of their specificity.

MATERIALS AND METHODS

Vibratory signals were studied in four species of pentatomid bugs: *Picromerus bidens*, *Troilus luridus*, *Zicrona caerulea*, and *Arma custos* F. The signals were recorded using a GZP-311 piezoelectric cartridge connected to a computer soundcard via a coupling amplifier. The data were saved and analyzed by means of Cool Edit Pro 2.0 software. A 3-cm shoot of the plant from which the insects were collected was attached to the cartridge in such a way that the head needle touched it with some tension. In order to record different types of signals, two males, a male and a female, or a solitary male or a female were placed onto the shoot. Only freshly cut shoots were used, since the dry ones were immediately abandoned by the insects.

The collection localities and recording temperatures are listed in table.

Recording conditions of the vibratory signals of Asopinae bugs

Species	Temperature during recording, °C	Collection locality and date
Arma custos	24	Krasnodar Territory, near Abrau-Dyurso, 11.V.2006
Picromerus bidens	22	Moscow Prov., Stupino District, Sokolova Pustyn, 24.IX.2003
Troilus luridus	22	Same locality, 13–16.IX.2003
Zicrona caerulea	23	Same locality, 06–12.IX.2003; Serpukhov District, near Pushchino-on-Oka, 23.VII.2006

RESULTS

Picromerus bidens

Signals produced by 15 males were recorded. The male rivalry song (Fig. 1, *1–5*) is a series of relatively short vibratory pulses with a stable repetition period. The series is 20 to 30 s long, the mean duration of a pulse is 279.9 ms, and the repetition period varies from 128 to 302 ms (the mean value is 260.1 ms). As can be seen from the sonogram, the signal spectrum is discrete and consists of three harmonics (Fig. 1, *5*). The frequencies of the 1st, 2nd, and 3rd harmonic vary within the ranges 50–80, 110–150, and 175–215 Hz, respectively. The alternating low- and high-amplitude vibratory pulses shown in the oscillograms (Fig. 1, *3–4*) belong to two different males.

While producing these signals, the males stay head to head raising their bodies on the straight middle and hind legs, and try to throw one another off the plant using their antennae and fore legs. The roll-call usually ends with one individual falling down from the shoot.

No specific calling or courtship signals were recorded in this species. An attempt at copulation started with the male approaching the female and feeling it with its antennae. If the female remained still, the male placed its fore legs on the posterior part of the female's abdomen and started copulation. At the same time, according to M. Gogala (2006), males of this species may produce a vibratory courtship signal by rhythmic rubbing of the legs. No such behavior during courtship was observed in our experiments, which may be accounted for by the physiological state of the insects or some differences in their living conditions and recording procedure. Under certain conditions, a mature female appears to be able of copulating without any additional stimulation. At the same time, it is also possible that bugs from different populations may have different acoustic repertoires.

Troilus luridus

We recorded signals produced by 4 males, either singly or in the presence of a female (Fig. 2, *1–4*). The signal is a series 15 to 20 s long composed of vibratory pulses. The mean duration of a pulse is 221.5 ms, and the repetition period varies from 118 to 256 ms (the mean value is 247.7 ms). The signal spectrum is discrete, consisting of two harmonics (Fig. 2, *4*). The frequencies of the 1st and 2nd harmonic vary within the ranges 85–140 and 185–240 Hz, respectively. Contrary to what was observed in the preceding species, the male's body is pressed to the substrate rather than raised on legs. After the signal, the female approaches the male and feels it with the antennae, after which copulation starts. The signal is therefore assumed to be a calling song (produced when the male cannot see the female). During the signal emission, the male's abdomen vibrates noticeably. Several males placed onto the same plant showed no rivalry behavior.

Zicrona caerulea

Signals produced by 8 males were recorded. The signal consists of relatively long vibratory pulses separated by irregular intervals (Fig. 2, *5–6*). The mean duration of a pulse is 1.98 s. As can be seen from the sonogram, the signal spectrum is discrete and consists of three harmonics (Fig. 2, *6*). The frequencies of the 1st, 2nd, and 3rd harmonic vary within the ranges 90–130, 200–280, and 320–360 Hz, respectively. We assume this to be a calling signal. Acoustic activity was always observed when the males were placed onto a new plant where no conspecific individuals had occurred before.

The bugs usually emit signals periodically while moving over the plant. When two insects meet, they feel one another with their antennae and fore legs. A male placed onto a new plant starts producing a signal if no other individual is present nearby. The males may emit signals in turn, after which, however,

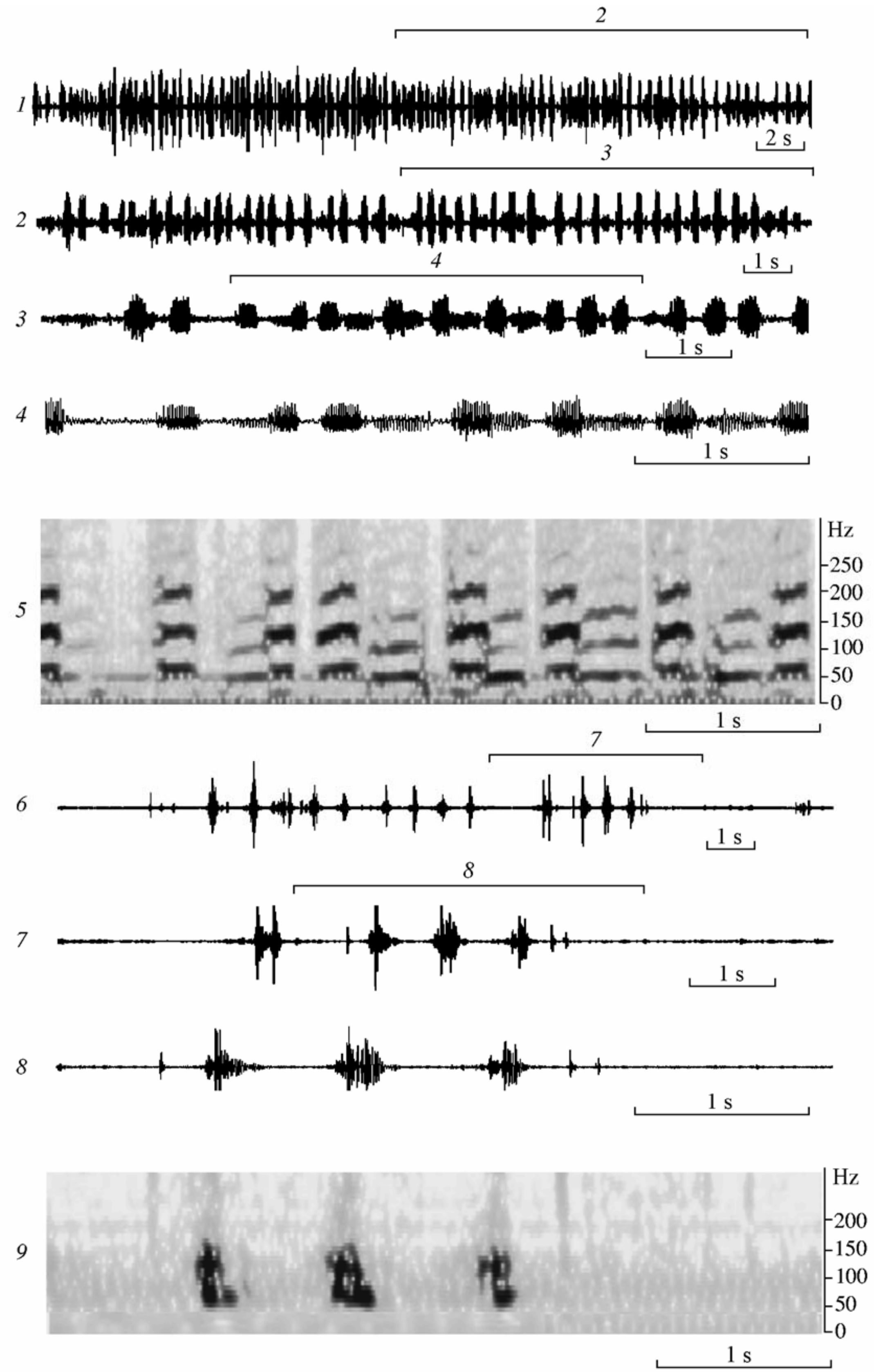

Fig. 1. Oscillograms (*1–4*, *6–8*) and sonograms (*5*, *9*) of vibratory signals emitted by bugs of the subfamily Asopinae: the rivalry signals of *Picromerus bidens* males (*1–5*) and a calling signal of an *Arma custos* male (*6–9*). The signals *2–4* and *7–8* are fragments of the preceding oscillograms shown at an expanded time scale.

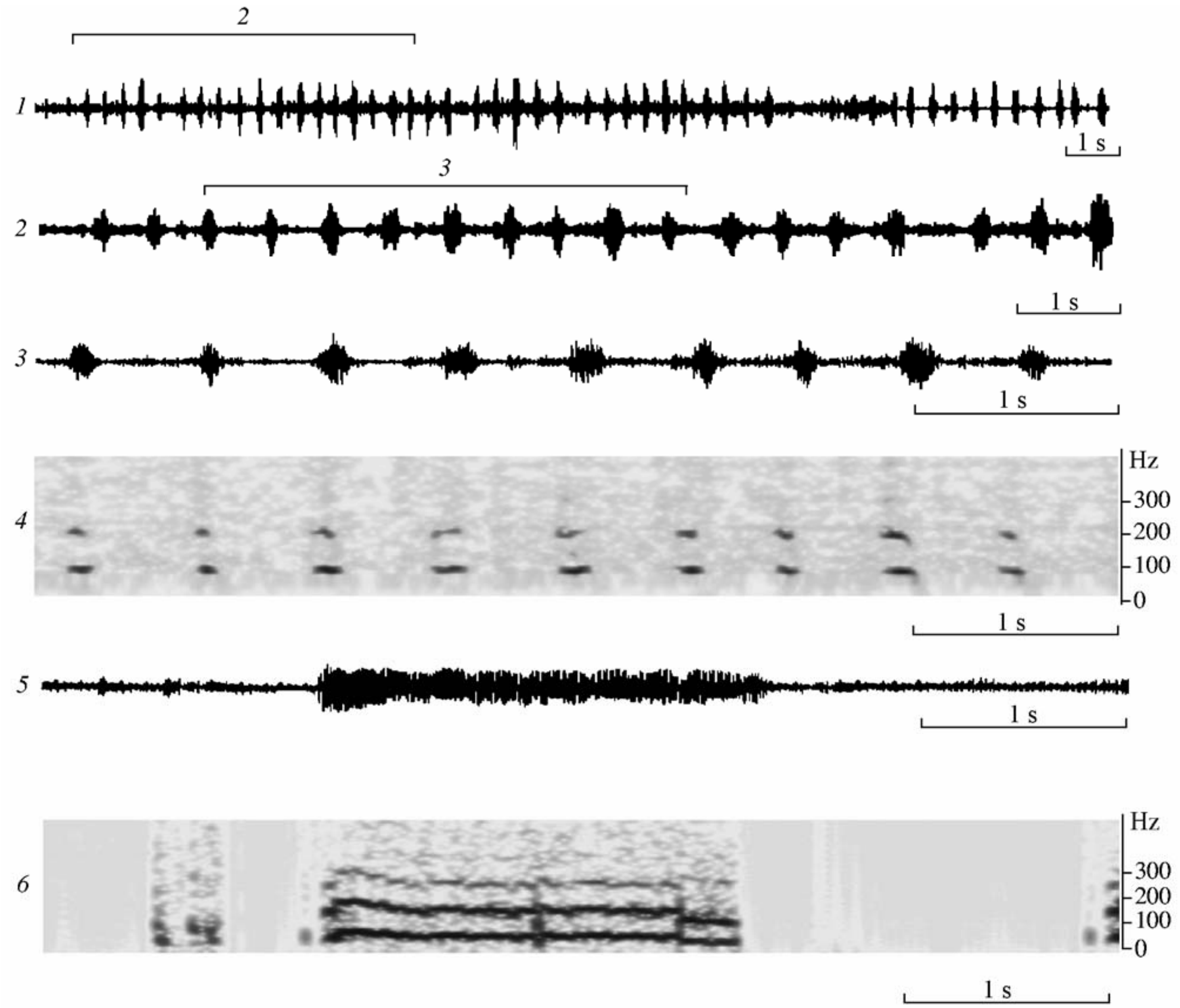

Fig. 2. Oscillograms (*1–3*, *5*) and sonograms (*4*, *6*) of calling vibratory signals emitted by bugs of the subfamily Asopinae: *Troilus luridus* (*1–4*) and *Zicrona caerulea* (*5*, *6*). The signals *2* and *3* are fragments of the preceding oscillograms shown at an expanded time scale.

none of them leaves the plant. During signal emission the insects usually stay motionless. The signal may be produced in the presence of females as well, and copulation may follow. It should be noted that the males do not emit signals when insects of other species, including the food objects, are present on the plant.

Arma custos

The signal produced by males of this species consists of short vibratory pulses emitted with highly irregular intervals. The individual pulses recorded varied from 223 to 412 ms (Fig. 1, *6–9*). The signal spectrum is continuous within the range from 50 to 200 Hz. During signal emission the insect moves over the plant feeling the substrate intensively with its antennae. This appears to be a calling signal.

In addition, during field research near Pushchino-on-Oka (Moscow Prov., Serpukhov) we observed a male of *Rhacognatus punctatus* L. to raise its body on the straight legs in front of the female, its abdomen vibrating. A similar behavioral act in *T. luridus* was accompanied by separate low-amplitude vibratory signals with indistinct amplitude-temporal structure.

DISCUSSION

The amplitude-temporal pattern of signals emitted by some species of Asopinae, for example, *P. bidens* (Fig. 1, *1–4*) and *Z. caerulea* (Fig. 2, *5–6*) is clearly species-specific. On the other hand, the rivalry signals of *P. bidens* (Fig. 1, *1–4*) and *T. luridus* (Fig. 2, *1–4*) have a similar temporal structure and differ only in the statistical parameters.

The plant stem is known to act as a frequency filter with a very complex nonlinear characteristic (Michelsen et al., 1982). The signal spectrum will therefore depend on physical parameters of a particular shoot and on the position of the singing insect relative to the vibration sensor. This phenomenon can be illustrated by the sonogram of the signals emitted by two individuals of *P. bidens* (Fig. 1, *5*). As can be seen from the figure, the peaks of the alternating signals produced by different individuals were shifted considerably because the insects were located at different distances from the piezoelectric cartridge. Thus, the most reliable characteristic of the frequency structure of the signal is the general shape of the spectrum (continuous or linear), whereas the position and relative amplitudes of individual peaks may vary. Besides the signals considered above, all the species emit low-amplitude vibratory pulses by friction of fore tibiae against the proboscis or middle and hind tibiae against the abdominal sternites. Such pulses have continuous spectra and in the sonograms appear identical to the vibrations caused by an insect moving on the substrate. Their amplitude-temporal patterns have no species-specific characters. It may be assumed that such vibrations are not communication signals but mere noise accompanying the mechanical activity of insects. Therefore, oscillograms and sonograms of these pulses are not shown here.

Thus, the vibratory signals recorded in bugs of the subfamily Asopinae can be classified into three functional types: male rivalry signals, male calling signals (in some cases probably acting also as courtship signals), and solitary vibratory pulses of a still unknown function. The male rivalry signals may serve as a calling song in some cases. According to our observations, reproductive behavior of *Picromerus bidens* and *P. conformis* H.-S. is not accompanied by vibratory communication. It should be emphasized that species of this subfamily have few signal types as compared to the rest of Pentatomidae, which additionally possess male territorial signals and female calling signals. This may be related to their ecological specificity (all members of this subfamily are predators) and the use of pheromone-based communication besides vibroacoustic signals. This assumption is confirmed by the fact that in all the cases, the insects emitted signals only in the presence of conspecific individuals or immediately after being placed onto the plant shoot.

The signal emission was interrupted by substrate vibrations caused by other factors, such as movements of the food object or manipulations of the researcher. The freezing behavior and a relatively restricted use of vibratory communication by all the members of Asopinae may be logically explained by the fact that vibratory signals can reveal the predator to its potential prey. This is confirmed by the data on other insect groups (Hymenoptera), where a parasitoid may seek its victim by substrate vibrations, while the victim may perceive the signals emitted by the parasitoid (Casas and Magal, 2006).

Bugs of the subfamily Asopinae, unlike the studied members of Pentatominae, do not use vibratory signals emitted by their wings. In addition, no ritualistic behavior using wings was observed in these insects.

The nymphs of *Z. caerulea* and *P. bidens* in most cases remain still or move over the substrate. Having met a conspecific individual the larva moves away without producing any vibratory signals.

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