

Vibrational signals in sympatric species of leafhoppers: Paralimnini (Homoptera: Cicadellidae: Deltocephalinae) in the valley of Irkut River, Eastern Siberia — a case study

Вибрационные сигналы симпатрических видов цикадок: исследование на примере Paralimnini (Homoptera: Cicadellidae: Deltocephalinae) в долине Иркутка, Восточная Сибирь

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KEY WORDS: leafhoppers, Cicadellidae, Paralimnini, vibrational signals, communication channels, acoustic niches, habitat preferences.

КЛЮЧЕВЫЕ СЛОВА: цикадки, Cicadellidae, Paralimnini, вибрационные сигналы, каналы связи, акустические ниши, биотопические предпочтения.

ABSTRACT. Comparative investigation of vibrational calling signals of leafhoppers of the tribe Paralimnini (Homoptera: Cicadellidae: Deltocephalinae) inhabiting the meadow and adjacent biotopes in the valley of Irkut River (Buryatia, Eastern Siberia) showed that the signal temporal pattern quite often is almost identical in different species. In all cases the forms producing similar signals were spatially isolated. It is supposed that these are differences in habitat preferences, which provide segregation of acoustic communication channels in such species.

РЕЗЮМЕ. Сравнительное исследование вибрационных призывных сигналов цикадок трибы Paralimnini (Homoptera: Cicadellidae: Deltocephalinae), населяющих луг и прилежащие биотопы в долине Иркутка (Бурятия, Восточная Сибирь), показало, что временной рисунок сигналов разных видов достаточно часто бывает практически идентичным. Во всех случаях формы, издающие сходные сигналы, оказывались пространственно изолированными. Вероятно, у таких видов именно различия в биотопической приуроченности обеспечивают разделение каналов акустической коммуникации.

Introduction

Presently it is known that sympatric species using intraspecific acoustic communication differ from each other in the structure of signals, thus each species occupying its own “acoustic niche” [Riede, 1996; Sueur, 2002; Bukhvalova, 2006; Tishechkin, 2008b]. In the special case that two species produce signals with sim-

ilar structure, they always demonstrate spatial, temporal or seasonal segregation. For instance, two Far-Eastern species of *Podismopsis* Zubowsky, 1900, *P. ussuriensis* Ikonnikov, 1911 and *P. genicularibus* (Shiraki, 1910) (Orthoptera: Acrididae) differ clearly from each other in the temporal pattern of calling songs. In the Siberian *P. poppiusi* (Miram, 1907), which is allopatric with two abovementioned ones the song sometimes is almost indistinguishable from this of *P. genicularibus* [Tishechkin, 2008a]. Similar situation is observed in a number of other species of Gomphocerinae (Orthoptera: Acrididae): the forms producing similar signals are either allopatric or inhabit different biotopes within the same territory [Bukhvalova, 2006; Tishechkin & Bukhvalova, 2009].

In small Auchenorrhyncha (Homoptera) using for communication vibrational signals transmitted via the solid substrate, i.e. plant stems and leaves the situation is somewhat more complex. Species producing similar signals can inhabit the same territory and biotope if dwell on different plant species. Since vibrational signals cannot be transmitted from one plant to another without physical contact between them, such forms, as a rule, does not perceive signals of each other [Tishechkin, 2007, 2008b].

On the other hand, in the most part of grass-dwelling forms males adopt “call-fly” strategy when searching for the conspecific female [Ichikawa, 1976; Hunt & Nault, 1991]. They move from one stem to another producing calling signals on each plant. As a result, the male can occasionally sing on non-host plant species. For example, during field recording of the signals of the plant-lice (Homoptera: Psyllinea) on *Achillea millefoli-*

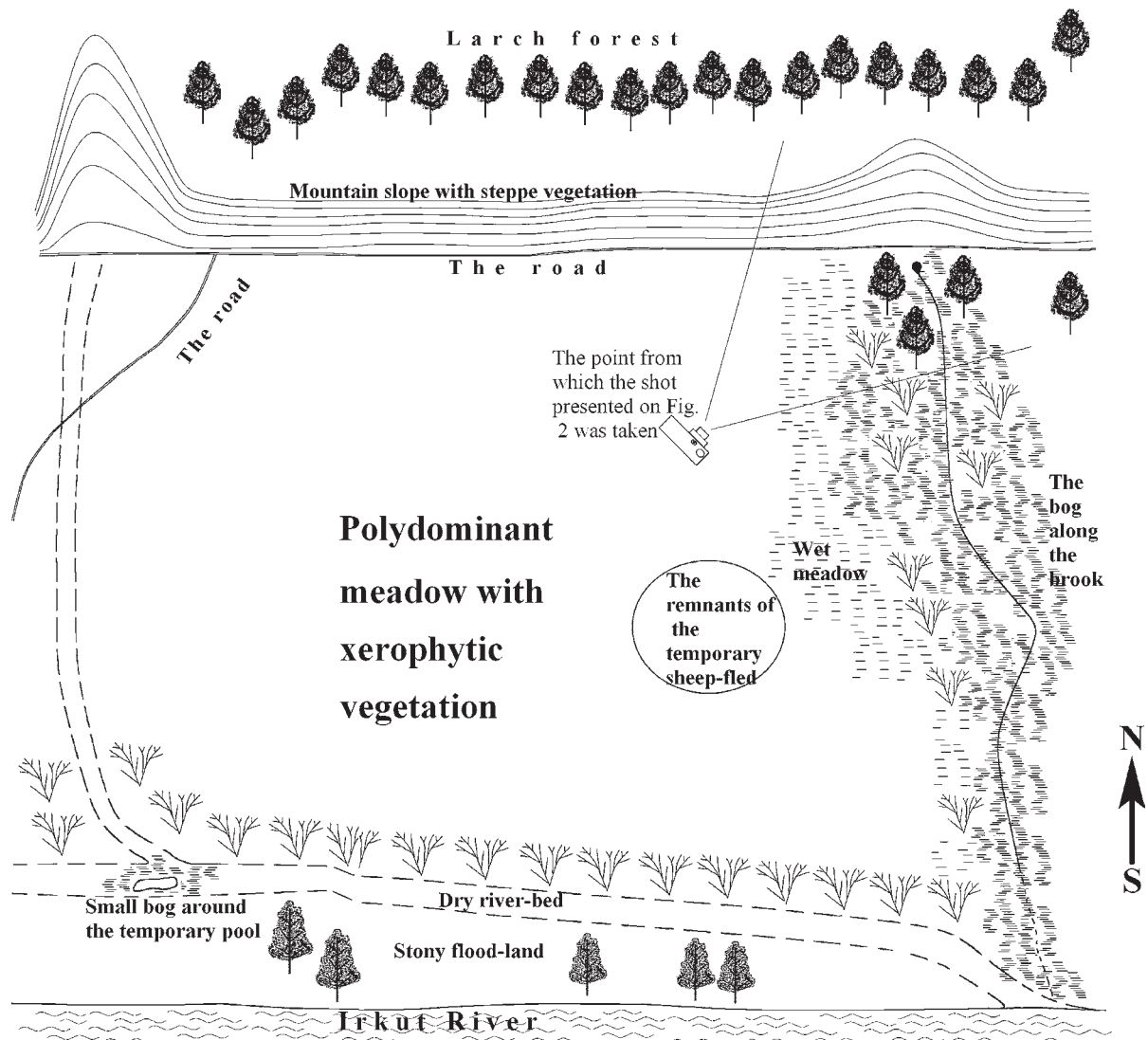


Fig. 1. The scheme of the spatial arrangement of the biotopes investigated (not to scale).

Рис. 1. Схема расположения исследованных биотопов (масштаб не соблюден).

um L. (Asteraceae) we have observed the male of *Graphocraerus ventralis* (Fallén, 1806) (Homoptera: Cicadellidae) producing calling signal on the stem to which the recording equipment was attached. It is common knowledge that this species feeds on various Gramineae; thus even the differences in host specialisation do not always provide acoustic isolation between sympatric species of leafhoppers. Apparently, in such cases segregation of communication channels in the forms producing similar signals can be provided only by differences in the biotope preferences. In the present paper the results of comparative analysis of signals of sympatric (i.e. inhabiting the same territory) species of Paralimnini (Homoptera: Cicadellidae: Deltocephalinae) supporting this hypothesis are presented.

Material and methods

Investigations were performed in the valley of Irkut River about 5 km west of Mondy Village (80 km west of Kyren), Buryatia, Eastern Siberia during the period 27 June – 5 July 2009.

The scheme and general view of the study area are provided on Figs 1–2. The main bed of Irkut River was bordered by narrow stripe of the stony flood-land with scattered clumps of trees and bushes, mainly *Populus suaveolens* Fischer and several species of willows. The flood-land was separated from the surrounding meadows by the dry river-bed with several small bogs and pools. Along the outer line of the dry river-bed the thickets of willows were growing. Then followed the meadow about 300 x 300 m situated on the flat bottom



Fig. 2. General view of the study area from the point shown in Fig. 1.

Рис. 2. Общий вид района исследований с точки, обозначенной на рис. 1.

of the valley. In the main (central) part it was dominated by rather xerophytic vegetation including several species of Gramineae, *Artemisia* sp. and *Potentilla* sp.; in certain places *Thalictrum petaloideum* L. (Ranunculaceae) was also numerous. On its eastern border the meadow gradually changed into the bog around the small brook flowing to the river. In the wet part of the meadow vegetation was more mesophytic and diverse: in appearance this part differed from the main area due to the presence of the bushes of *Pentaphylloides fruticosa* (L.) O. Schwarz (Rosaceae) and bright-orange flowers of *Trollius asiaticus* L. (Ranunculaceae). The bog itself was dominated by several species of sedges (*Carex* spp.); in certain places the thickets of willows and young birches were present. Also, several larch trees (*Larix sibirica* Ledeb.) were growing near the spring. The road going along the mountain slope covered with steppe vegetation formed the northern border of the meadow. In addition, in the eastern part of the meadow there was a place differing much from the surrounding areas due to the utter absence of dicotyledonous plants. Evidently, the temporary sheep-fled was situated here some time ago; now it was overgrown with two or three species of Gramineae.

The representatives of Paralimnini were collected in different parts of the meadow (in the main part, more

wet area on the eastern border and on the place of the former sheep-fled), in the bogs in the dry river-bed and along the brook and on the steppe slope. Quantitative investigations of the leafhopper fauna, as well as special studies of species composition of vegetation were not performed. Data on distribution of species of Paralimnini in different biotopes are given in the Table. It should be noted, that in certain cases single specimens were also found outside their typical habitats.

Vibrational signals were registered by means of the crystal gramophone cartridge GZP-311 connected to the microphone input of minidisk recorder Sony Walkman MZ-NH900 via the custom-made matching amplifier. Recordings were made in the tent immediately after collecting the insects. Temperature during recording averaged from 24–26 to 32–35 °C. Only calling signals produced by male for attraction of conspecific female were analysed. In two last species in the Table, *Pantallus alboniger* (Lethierry, 1889) and *Psammodettix koeleriæ* Zachvatkin, 1948, we failed to make signal recordings.

The material examined is deposited in the collection of the Zoological Museum of M.V. Lomonosov Moscow State University. Interpretation of *Rosenus stepposus* Vilbaste, 1965 and *Falcitettix sibiricus* Linnavuori, 1953 is accepted after Vilbaste [1980] and Emelyanov [1989], respectively.

Results and discussion

In contrast to many other species of small Auchenorrhyncha, the most part of representatives of Paralimnini produce rather simple calling signals consisting of single or regularly repeated syllables [Tishechkin, 2000, 2007]. For this reason signal temporal pattern in representatives of this tribe quite often is similar or even indistinguishable in different species.

Syllable repetition period in Paralimnini usually varies to a great extent and cannot provide reliable diagnostic characters (Figs 5, 7, 11, 16). Among species studied *Sorhoanus xanthoneurus* (Fieber, 1869) is the only exception: normally, its song consists of regularly repeated syllables and gradually increases in amplitude towards the end (Figs 13–15).

The shape of syllables in a number of species is also variable due to irregular amplitude modulations (Figs 8–10, 25–28, 30–31). Occasionally certain syllables consist of several fragments separated from each other by distinct amplitude minimums, but in other signals such modulations are almost entirely flattened (Figs 25–26 and 27–28). As a result, the duration of syllables remains the only reliable parameter for discrimination between signals of different species. However, the most

part of species studied can be united in several groups according to this character (Table). Within each group syllable duration has almost the same values in different species.

The first group includes two species of *Psammotettix* Haupt, 1929, namely, *P. koreanus* (Matsumura, 1915) and *P. striatus* (Linnaeus, 1758). Their signals consist of short syllables, repeated with more or less regular, but variable intervals (Figs 3–6). The ranges of variability of syllable duration in these species overlap almost completely (Table). However, this is no barrier to successful communication because these species were never found in the same biotope. *P. koreanus* was collected on the mountain slope with steppe vegetation, whereas *P. striatus* inhabited the main part of the meadow including the place of the former temporary sheep-fled. Thus, these species demonstrated distinct spatial segregation in spite of the fact that the biotopes inhabited by each one were separated only by a narrow border.

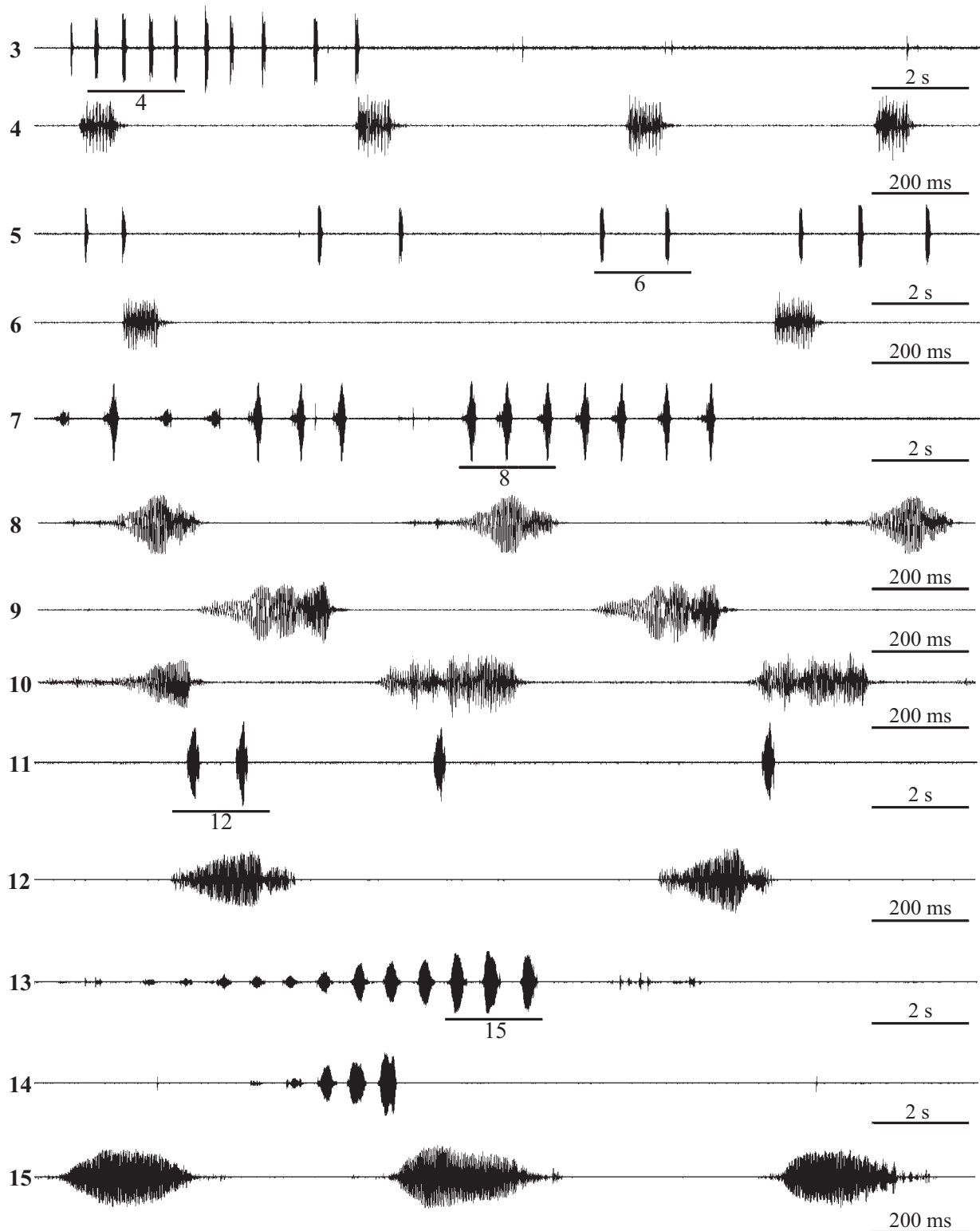
Cosmotettix paludosus (Ball, 1899), *Sorhoanus xanthoneurus* and *Rosenus stepposus* form the next group of species producing similar signals (Figs 7–15). The shape of syllables in all three ones is almost identical; in *S. xanthoneurus* syllables as a rule are grouped into

Table. Duration of syllables of calling signals of Paralimnini, temperature during recording and distribution of species by biotopes. Bold lines separate the groups of species producing signals with similar temporal pattern. Таблица. Длительность серий в призывных сигналах Paralimnini, температура во время записи и распределение видов по биотопам. Группы видов, издающих сигналы со сходным временным рисунком, разделены жирными линиями.

Species	Temperature during recording, °C	Duration of syllable, ms	Biotope					
			Meadow			The bog in the dry river-bed	The bog along the brook	Steppe slope
			Main part	The former sheep-fled	Eastern (wet) part			
<i>Psammotettix koreanus</i> (Matsumura, 1915)	24–25	60–110						++
<i>P. striatus</i> (Linnaeus, 1758)	25	70–110	++	++				
<i>Cosmotettix paludosus</i> (Ball, 1899)	27	240–330					++	
<i>Rosenus stepposus</i> Vilbaste, 1965	25–26	240–270	++					
<i>Sorhoanus xanthoneurus</i> (Fieber, 1869)	25–26	280–360				++	+	
<i>P. kolosvarensis sibiricus</i> Vilbaste, 1980	25–27	120–250	++					
<i>Diplocolenus abdominalis</i> (Fabricius, 1803)	25–26	120–220			++			
<i>Hebecephalus changai</i> Dlabola, 1965	31–33	550–1500		++	+			
<i>Sorhoanus hilaris</i> (Melichar, 1900)	31	650–1000	++					
<i>Mocuellus hordei</i> Emelyanov, 1964	24–26	650–900	++	+	+			
<i>Falcitettix sibiricus</i> Linnavuori, 1953	32–35	2000–2800	++	+				
<i>Tiaratus caricis</i> Emelyanov, 1961	25–27	50–60	++	+	++			
<i>Pantallus alboniger</i> (Lethierry, 1889)	Not recorded		+					
<i>Psammotettix koeleriae</i> Zachvatkin, 1948	Not recorded							+

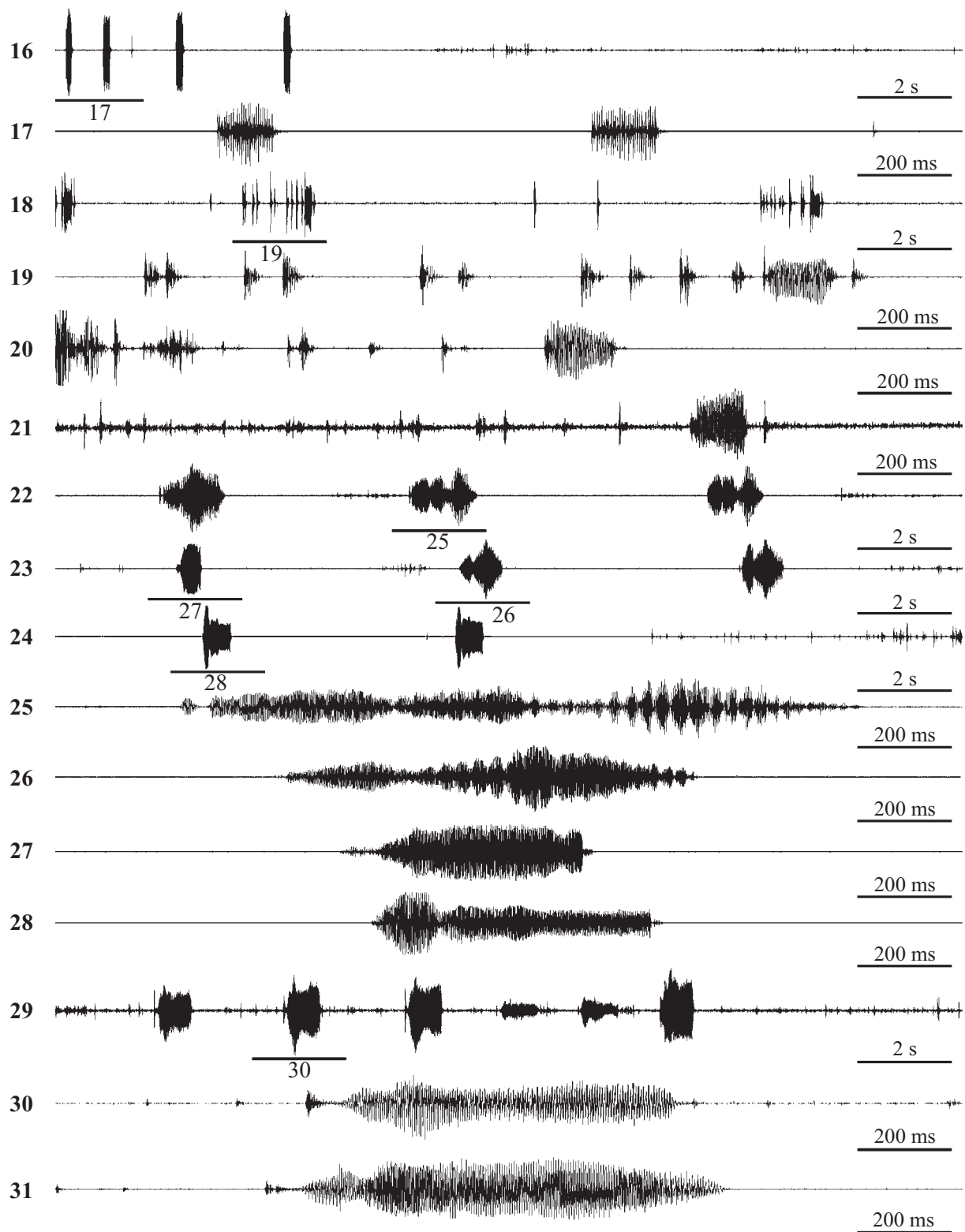
++ — numerous, + — single specimens

*For *D. abdominalis* and *M. hordei* the values of duration of the main part of signal (i.e. excluding initial short pulses) are given.



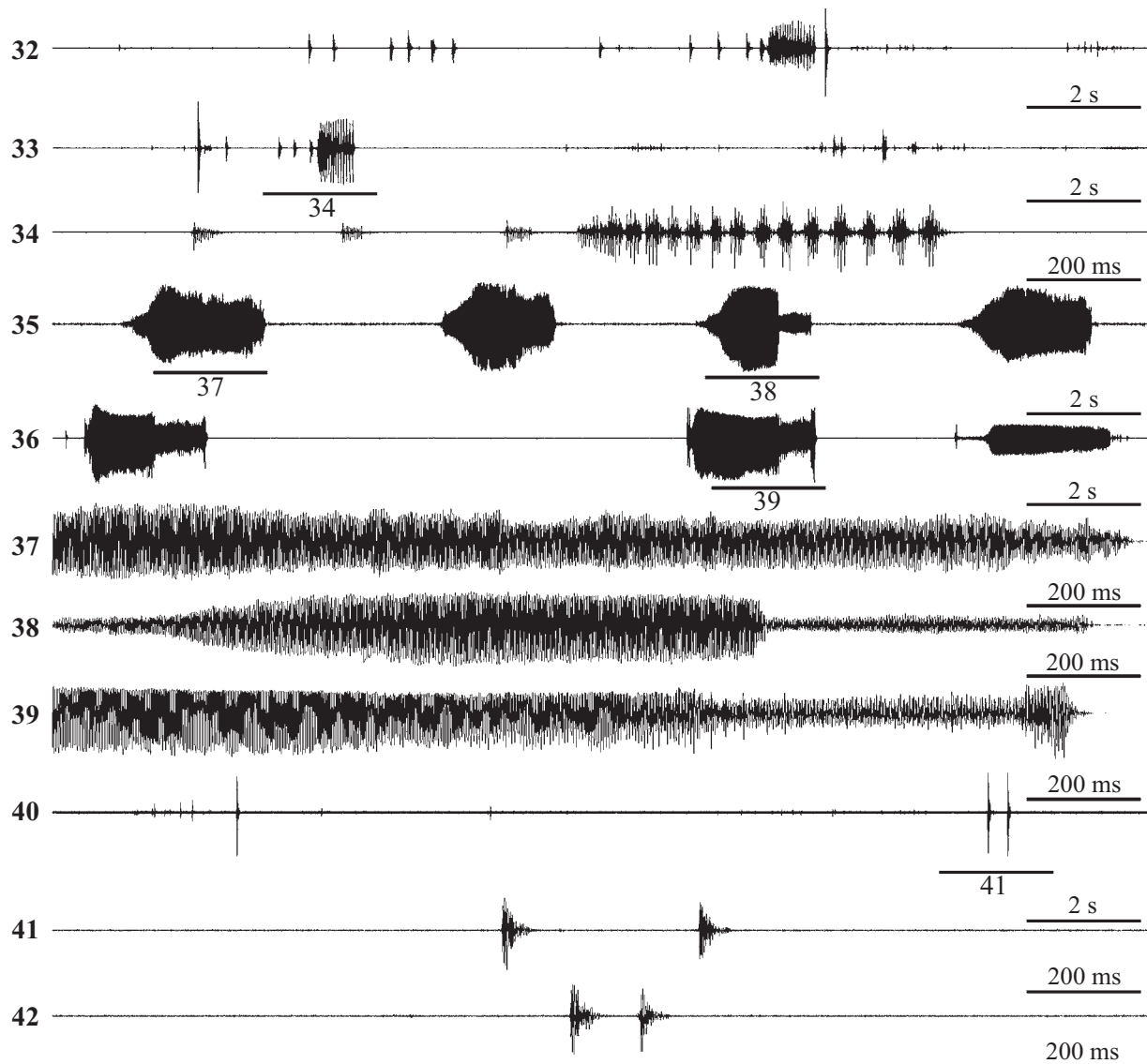
Figs 3–15. Oscillograms of calling signals of Paralimnini. 3–4 — *Psammotettix koreanus*; 5–6 — *P. striatus*; 7–10 — *Cosmotettix paludosus*; 11–12 — *Rosenus stepposus*; 13–15 — *Sorhoanus xanthoneurus*. Faster oscillograms of the parts of signals indicated as “4”, “6”, “8”, “12” and “15” are given under the same numbers.

Рис. 3–15. Осциллограммы призывных сигналов Paralimnini. 3–4 — *Psammotettix koreanus*; 5–6 — *P. striatus*; 7–10 — *Cosmotettix paludosus*; 11–12 — *Rosenus stepposus*; 13–15 — *Sorhoanus xanthoneurus*. Фрагменты сигналов, помеченные цифрами “4”, “6”, “8”, “12” и “15”, представлены при большей скорости развёртки на осциллограммах под соответствующими номерами.



Figs 16–31. Oscillograms of calling signals of Paralimnini. 16–17 — *Psammotettix kolosvarensis sibiricus*; 18–21 — *Diplocolenus abdominalis*; 22–28 — *Hebecephalus changai*; 29–31 — *Sorhoanus hilaris*. Faster oscillograms of the parts of signals indicated as “17”, “19”, “25–28” and “30” are given under the same numbers.

Рис. 16–31. Осциллограммы призывных сигналов Paralimnini. 16–17 — *Psammotettix kolosvarensis sibiricus*; 18–21 — *Diplocolenus abdominalis*; 22–28 — *Hebecephalus changai*; 29–31 — *Sorhoanus hilaris*. Фрагменты сигналов, помеченные цифрами “17”, “19”, “25–28” и “30”, представлены при большей скорости развёртки на осциллограммах под соответствующими номерами.



Figs 32–42. Oscillograms of calling signals of Paralimnini. 32–34 — *Mociellus hordei*; 35–39 — *Falcitettix sibiricus*; 40–42 — *Tiaratus caricis*. Faster oscillograms of the parts of signals indicated as “34”, “37–39” and “41” are given under the same numbers.

Рис. 32–42. Осциллограммы призывных сигналов Paralimnini. 32–34 — *Mociellus hordei*; 35–39 — *Falcitettix sibiricus*; 40–42 — *Tiaratus caricis*. Фрагменты сигналов, помеченные цифрами “34”, “37–39” и “41”, представлены при большей скорости развёртки на осциллограммах под соответствующими номерами.

echemes, whereas in two other species they can follow each other with irregular intervals. Similarly to the previous case, these species for the most part were spatially isolated. *R. stepposus* inhabited the meadow with the exception of its eastern wet border; *C. paludosus* was found only in the bog near the brook. *S. xanthoneurus* formed the dense compact population in the small bog in the dry river-bed. Several specimens were also found in the bog near the brook, still *C. paludosus* was far more numerous here. Since the songs of the latter two species have certain differences, their coexistence in the same biotope is possible. On the other hand, the pattern and repetition period of syllables in these forms are almost identical; apparently, this is the reason why they demonstrate the tendency for habitat segregation.

Calling signals of *Psammotettix kolosvarensis* (Matsumura, 1908) and *Diplocolenus abdominalis* (Fabricius, 1803) are also similar both in syllable duration and temporal pattern (Figs 16–21). In *D. abdominalis* a train of short pulses usually precede the syllable, but occasionally this component is almost reduced (Fig. 21). *P. kolosvarensis* inhabited the main part of the meadow, whereas *D. abdominalis* occurred only in the wet places next to the bog around the brook.

Hebecephalus changai Dlabola, 1965 and *Sorhoanus hilaris* (Melichar, 1900) being indistinguishable in the syllable duration (Figs 22–31) also were spatially separated. The former species was found only on graminaceous vegetation on the place of the former temporary sheep-fled; occasionally, single specimens were col-

lected in the wet part of the meadow near the bog. On the contrary, the latter one inhabited only the places with xerophytic vegetation in the main part of the meadow.

The signal of *Mocuellus hordei* Emelyanov, 1964 has rather complex structure and differ much from these in other Paralimnini (Figs 32–34). In *Falcitettix sibiricus* calling signal is a very long monotonous fragment, far exceeding in duration the syllables of sympatric species (Figs 35–39, Table). In *Tiaratus caricis* Emelyanov, 1961 only very short clicks were registered; they also differ distinctly from the songs of sympatric forms (Figs 40–42).

Therefore, as can be seen from the data presented, the similarity of the temporal pattern of calling signals in certain groups of small Auchenorrhyncha is not a rare case. In 9 of 12 studied species of Paralimnini the structure of signals is not unique and is more or less similar with this in one or two other ones. Moreover, species producing signals with similar structure quite often can be found in the same locality in the places situated at a distance of 10–15 m from each other and are formally sympatric. Only close investigation of their spatial distribution allows revealing their isolation. Thus, segregation of vibrational communication channels in grass-dwelling leafhoppers, evidently, can be provided by differences in habitat preferences. For polyphagous or oligophagous sympatric species having the same breeding season this is the only way to avoid occupying the same acoustic niche. Species producing signals with similar pattern were never found in the same biotope in the region of our investigations. These data are in good agreement with the results of the previous investigations of the examples of similarity of signals in Paralimnini [Tishechkin, 2007] as well as in other small Auchenorrhyncha [Tishechkin, 2008b] and in the grasshoppers of the subfamily Gomphocerinae (Orthoptera: Acrididae) [Tishechkin & Bukhvalova, 2009].

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References

- Bukhvalova M.A. 2006. Partitioning of acoustic transmission channels in grasshopper communities // S. Drosopoulos, M.F. Claridge (eds.). *Insect Sounds and Communication. Physiology, Behaviour, Ecology and Evolution*. Boca Raton, London, New York: CRC Press, Taylor and Francis Group. P.199–205.
- Emelyanov A.F. 1989. [New species of leafhoppers (Homoptera, Cicadellidae) from the Mongolian People’s Republic and adjacent regions of the USSR] // *Nasekomye Mongolii*. Leningrad: “Nauka” Publ. Vol.10. P.118–125 [in Russian].
- Hunt R.E. & Nault L.R. 1991. Roles of interplant movement, acoustic communication, and phototaxis in mate-location behaviour of the leafhopper *Graminella nigrifrons* // *Behavioral Ecology and Sociobiology*. Vol.28. P.315–320.
- Ichikawa T. 1976. Mutual communication by substrate vibration in the mating behaviour of planthoppers (Homoptera, Delphacidae) // *Appl. Entomol. Zool.* Vol.11. No.1. P.8–23.
- Riede K. 1996. Diversity of sound-producing insects in a Bornean lowland rain forest // *Tropical Rainforest Research*. Kluwer Acad. Publ., Netherlands. P.77–84.
- Sueur J. 2002. Cicada acoustic communication: potential sound partitioning in a multispecies community from Mexico (Hemiptera: Cicadomorpha: Cicadidae) // *Biol. J. Linn. Soc.* Vol.75. P.379–394.
- Tishechkin D.Yu. 2000. Vibrational communication in Aphrodinae leafhoppers (Deltocephalinae auct., Homoptera: Cicadellidae) and related groups with notes on classification of higher taxa // *Russian Entomol. J.* Vol.9. No.1. P.1–66.
- Tishechkin D.Yu. 2007. Similar calling signals in different species of leafhoppers (Homoptera: Cicadellidae): an example of Paralimnini // *Russian Entomol. J.* Vol.16. No.2. P. 265–272.
- Tishechkin D.Yu. 2008a. Calling songs of grasshoppers of the genus *Podismopsis* (Orthoptera: Acrididae: Gomphocerinae) and potentialities of use of acoustic characters for discrimination between species of the genus // *Russian Entomol. J.* Vol.17. No.3. P.259–272.
- Tishechkin D.Yu. 2008b. On the similarity of temporal pattern of vibrational calling signals in different species of Fulgoroidea (Homoptera: Auchenorrhyncha) // *Russian Entomol. J.* Vol.17. No.4. P.343–351.
- Tishechkin D.Yu. & Bukhvalova M.A. 2009. Acoustic communication in grasshopper communities (Orthoptera: Acrididae: Gomphocerinae): segregation of acoustic niches // *Russian Entomol. J.* Vol.18. No.3. P.165–188.
- Vilbaste Yu.G. 1980. [Fauna of Cicadinea of Tuva]. Tallinn: Valgus Publ. 219 pp. [in Russian, with English summary].