

## Similar calling signals in different species of leafhoppers (Homoptera: Cicadellidae): an example of Paralimnini

## Сходные призывные сигналы у разных видов цикадок (Homoptera: Cicadellidae): исследование на примере Paralimnini

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КЛЮЧЕВЫЕ СЛОВА: цикадовые, систематика, диагностические признаки, вибрационные сигналы, Paralimnini, Cicadellidae.

**ABSTRACT.** Examples of similarity of calling signals in different species of Paralimnini (Homoptera: Cicadellidae) are discussed. Species producing signals with identical structure never come into acoustic interactions with each other due to differences in host specialisation, habitat preferences or geographical distribution. Therefore, using of bioacoustic characters in systematics without considering the data on biology and distribution can lead to wrong taxonomic conclusions, because the similarity or even absolute identity of structure of signals in different forms is not always unequivocal evidence of their synonymy.

**РЕЗЮМЕ.** Рассмотрены примеры сходства призывных сигналов у разных видов Paralimnini (Homoptera: Cicadellidae). Во всех случаях виды, издающие идентичные по структуре сигналы, не вступают в акустический контакт по причине различий в кормовой специализации, биотопической приуроченности или географическом распространении. Таким образом, использование биоакустических признаков в систематике без учёта данных по распространению и биологии может привести к ошибочным таксономическим заключениям, поскольку сходство или даже полная идентичность сигналов разных форм отнюдь не всегда является доказательством их синонимии.

It is well known that these are differences in temporal pattern of calling signals, which provide reproductive isolation in many species of insects using acoustic communication. For this reason, analysis of signals is successfully employed in taxonomy for discrimination between cryptic species and for establishing of status of closely related forms showing small morphological differences. Similarity of signal

patterns in different forms does not always indicates that they belong to the same species, however.

For example, in certain grasshoppers, e.g., in European *Euchorthippus* and in a number of *Omocestus* species (Orthoptera: Acrididae) temporal pattern of calling signals is quite similar and sometimes is almost identical [Ragge & Reynolds, 1984; Ragge, 1986]. Recent investigation of calling songs in grasshopper communities demonstrated that the complex of temporal parameters of signal determines for each species its own place in the acoustic environment of the community, so-called acoustic niche, which is a part of the ecological niche as a whole [Bukhvalova, 2006]. Signals of species belonging to the same community differ from each other, i.e. occupy different acoustic niches, whereas in members of different communities they sometimes are almost indistinguishable in temporal pattern. This is no barrier to successful communication because such species never come into acoustic interactions with each other.

Similar situation takes place in Psyllinea (Homoptera). Temporal pattern of calling songs in this group for the most part is species-specific. Nonetheless, in a number of species signals are quite similar and cannot be told apart with certainty [Tishechkin, 2006]. Occasionally, such species are formally sympatric, i.e. live in the same biotope. Still, it should be remembered, that psyllids use not airborne sounds, but substrate-borne vibrations for their communication. Such signals cannot be transmitted from one plant to another without physical contact. Consequently, forms with narrow host specialization dwelling on different plant species as a rule cannot hear the signals of each other.

Small Auchenorrhyncha (Homoptera: Cicadinea with the exception of singing cicadas, Cicadidae) also

produce substrate-borne vibratory signals. Although a great number of representatives of many orders of insects possess well-developed acoustic communication, signals of Cicadinea stands out because of most elaborate temporal structure. Even in closely related species the pattern of calling songs sometimes is completely different. Thus, in many taxa of Cicadinea acoustic analysis provides useful characters for discrimination between cryptic species [for example, Tishechkin, 1999a, b, 2002]. By contrast, in certain tribes of leafhoppers (Cicadellidae) and in some Fulgoroidea the structure of signals is rather simple and uniform. Differences between signals of closely related species in such groups are indistinct or absent. Therefore, signal analysis for taxonomic purposes must be used with caution in this situation.

Certain examples of similarity of calling signals in the representatives of the tribe Paralimnini (Homoptera: Cicadellidae: Deltocephalinae) will be discussed here.

Recordings of vibratory signals were made by means of piezo-electric crystal gramophone cartridge connected to the microphone input of cassette recorder "Elektronika-302-1" or minidisk recorder Sony Walkman MZ-NH900 via the matching amplifier. In all cases manual mode of recording level control was

used. Analysis of recordings was performed on PC provided with analog/digital converter and appropriate software.

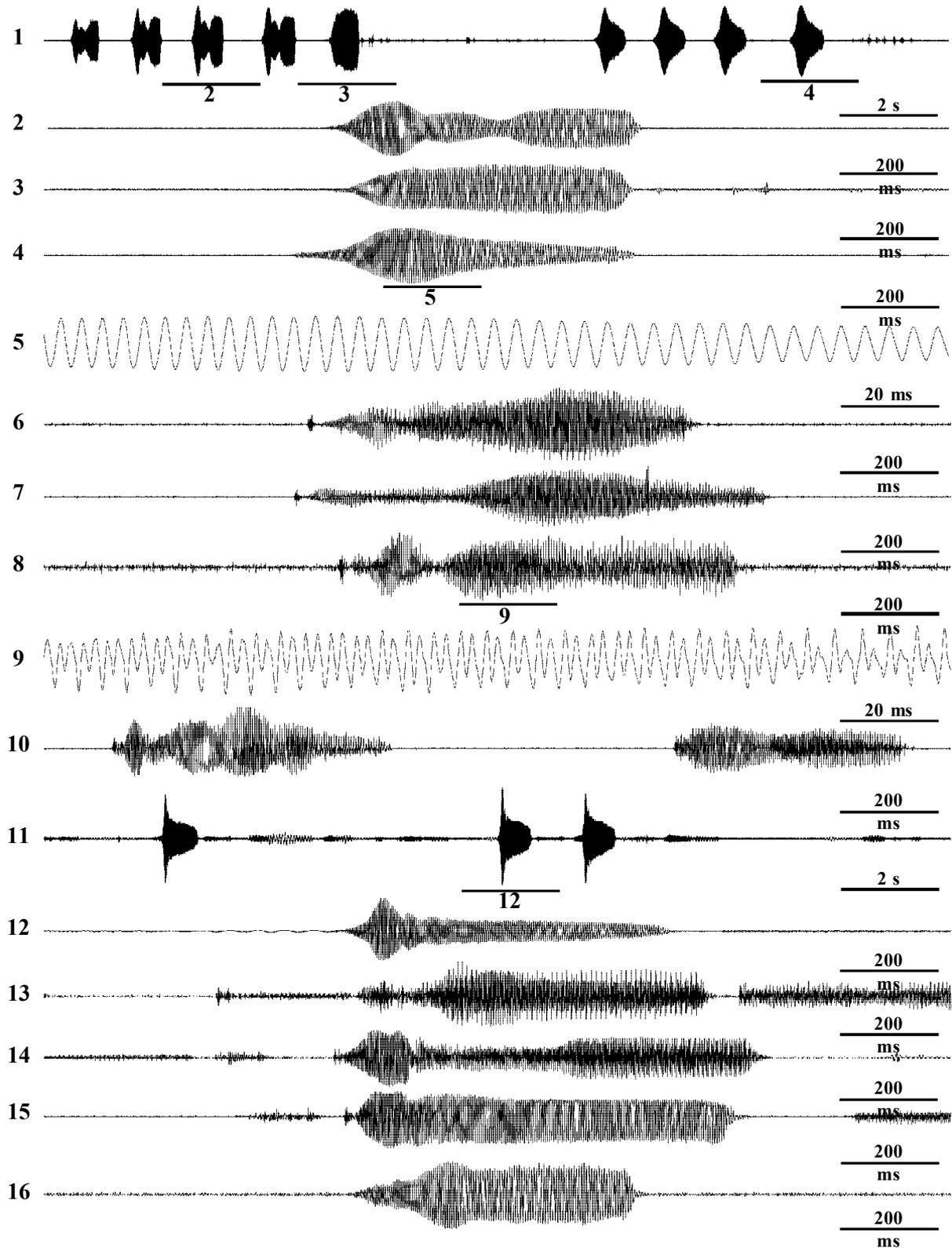
Data for recordings of signals of leafhoppers used in the paper are given in the Table.

It is apparent, that in allopatric species differences in structure of communication signals plays no role in reproductive isolation. Consequently, such forms can produce similar signals and still exist as separate species. In certain Paralimnini that is the case.

*Sorhoanus medius* (Mulsant et Rey, 1855) and *S. hilaris* (Melichar, 1900) are common and abundant steppe-dwelling species feeding on grasses (Poaceae). They inhabit similar biotopes, but the range of the former one includes Europe, Kazakhstan and southern part of Western Siberia, whereas the latter occurs in steppes of Eastern Siberia (Irkutsk Area, Transbaikalia, Yakutia) and in Central and Eastern Mongolia. In both species, calling signals consist of single or regularly repeating short fragments with variable shape (Figs 1–10 and 11–16). Occasionally, fragments of quite different shape present in the signals of specimens from the same population (Fig. 1). Inner structure of signals also varies greatly. Signal consists either of sine waves (Figs

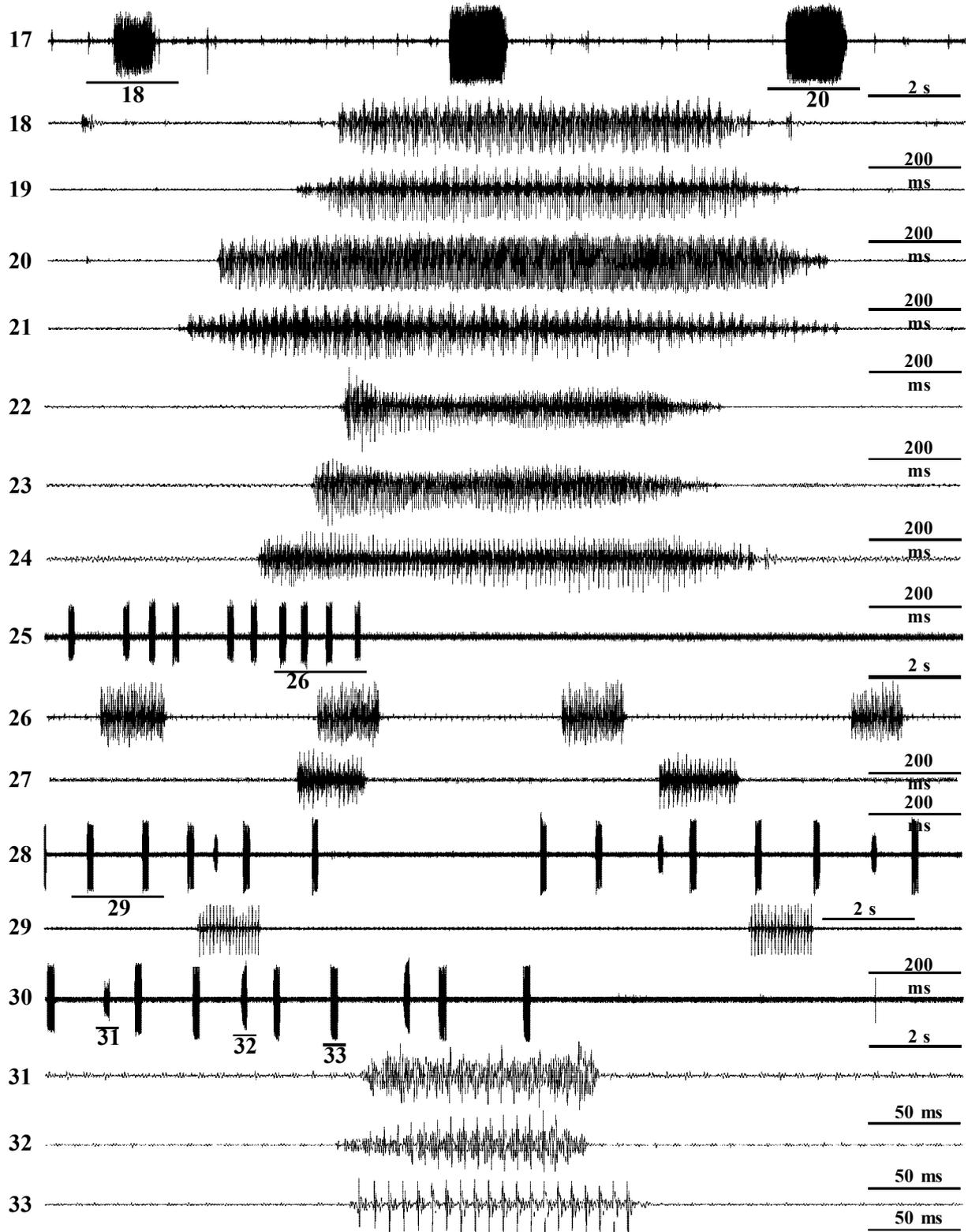
Data for recordings of calling signals of the studied species of Paralimnini  
Данные о записях призывных сигналов изученных видов Paralimnini

Species	Locality	Air temperature during recording, °C
<i>Sorhoanus medius</i> (Mulsant et Rey, 1855)	1. Moscow Area, Serpukhov Region, the valley of Oka Riv. E of Luzhki Vill.	21
	2. Saratov Area, steppe on the hills about 15 km WSW of Khvalynsk.	23-25
	3. Altai, southern end of Teletskoe Lake, the valley of Chulyshman Riv. in the env. of Balykcha Vill.	28
<i>S. hilaris</i> (Melichar, 1900)	1. Buryatia, 10 km E of Onokhoy (about 60 km E of Ulan-Ude), steppe in the valley of Bryanka Riv.	27-30
	2. SE of Chita Area, Klichinskiy Ridge near the crossing with Urulyunguy Riv. (15 km W of Klichka Town)	27
<i>Mocuellus collinus</i> (Boheman, 1850)	Moscow Area, Voskresensk Region, env. Beloozerskiy Town.	20
<i>M. angustiarum</i> Tishetshkin, 1994	North Ossetia, Alagir Gorge (the valley of Ardon Riv.), arid depression in the env. of Zintsar Vill.	20-21
<i>Psammotettix atropidicola</i> Emeljanov, 1962	Volgograd, gramineous vegetation on saline land.	23, 25-27
<i>P. kaszabi</i> Dlabola, 1961	Dosang Railway Station about 60 km N of Astrakhan'. <i>Artemisia</i> subg. <i>Seriphidium</i> on saline land.	26
<i>Diplocolenus frauenfeldi</i> (Fieber, 1869)	1. E of Saratov Area, 4-5 km N of Ozinki Town.	26-27
	2. Buryatia, 10 km E of Onokhoy (about 60 km E of Ulan-Ude), glades in dry pine forest.	22-23
<i>D. suttholli</i> Vilbaste, 1980	Buryatia, 10 km E of Onokhoy (about 60 km E of Ulan-Ude), steppe in the valley of Bryanka Riv.	24-25
<i>D. bohemani</i> (Zetterstedt, 1840)	1. Moscow Area, Voskresensk Region, env. Beloozerskiy Town.	21
	2. Altai, southern end of Teletskoe Lake.	24-25



Figs 1-16. Oscillograms of calling signals of males: 1-10 — *Sorboanus medius*; 1-5 — from Saratov Area; 6-9 — from Moscow Area; 10 — from Altai; 11-16 — *S. bilaris*; 11-15 — from Buryatia; 16 — from Chita Area. Parts of signals indicated as 2-5, 9 and 12 are given on oscillograms under the same numbers.

Рис. 1-16. Осциллограммы призывных сигналов самцов: 1-10 — *Sorboanus medius*; 1-5 — из Саратовской обл.; 6-9 — из Московской обл.; 10 — с Алтая; 11-16 — *S. bilaris*; 11-15 — из Бурятии; 16 — из Читинской обл. Фрагменты сигналов, обозначенные цифрами 2-5, 9 и 12, представлены на осциллограммах под такими же номерами.



Figs 17–33. Oscillograms of calling signals: 17–21 — *Mocuellus collinus*; 22–24 — *M. angustiarum*; 25–27 — *Psammotettix atropidicola*; 28–33 — *P. kaszabi*. Parts of signals indicated as 18, 20, 26, 29 and 31–33 are given on oscillograms under the same numbers.

Рис. 17–33. Осциллограммы призывных сигналов: 17–21 — *Mocuellus collinus*; 22–24 — *M. angustiarum*; 25–27 — *Psammotettix atropidicola*; 28–33 — *P. kaszabi*. Фрагменты сигналов, обозначенные цифрами 18, 20, 26, 29 и 31–33, представлены на осциллограммах под такими же номерами.

4–5), or of vibrations with more complex and less regular shape (Figs 8–9). Evidently, variability of waves shape is a result of different transmission properties of the parts of twigs or stems and of differences in relative position of singing insect and vibrotransducer detecting vibrational signal. So, as is seen from the oscillograms on Figs 1–16, no clear-cut distinction exists between calling signals of these two species.

*Mocuellus collinus* (Boheman, 1850) and *M. angustiarum* Tishetshkin, 1994 is another pair of species indistinguishable in structure of acoustic signals. *M. collinus* is a transpalearctic species dwelling on grasses in various open habitats. *M. angustiarum* was found only in highly peculiar mountain steppes in arid depression between the ridges of North Ossetia (North Caucasus) and, apparently, is endemic of this region. Signals of both species are syllables, i.e. successions of more or less distinct pulses with total duration approximately from 0.8 up to 1.5 s (Figs 17–21 and 22–24). They are similar both in temporal pattern and in duration of series. On average, syllables of *M. angustiarum* are somewhat shorter; still, signals of two species overlap almost completely in this parameter.

Calling signals of the most part of the studied species of *Psammotettix* have the same scheme of temporal pattern. They consist of short syllables following each other with more or less regular intervals [Tishechkin, 1999c, 2000]. Signals of different species differ from each other mostly in the length of syllables. However, in certain cases they overlap in this character as well. *Psammotettix kaszabi* Dlabola, 1961 and *P. atropidicola* Emeljanov, 1962 are an example. Syllables repetition period in their signals is rather variable and has similar values in both species (Figs 25 and 28, 30) as well as the duration of syllables (Figs 26–27, 29, 48). Certain differences in the structure of pulses is of no concern, because the shape of waves in substrate-transmitted vibrations depends to a large extent on the physical properties of a substrate, as it was mentioned above. As a result, signals of insects singing in different points on the same plant are somewhat different (Figs 30–33).

Both species dwell on saline lands in southwestern part of European Russia and in Kazakhstan and often can be found in the same habitat, e.g., in the Lower Volga region. On the other hand, their host specialisation is quite different. *P. kaszabi* feeds on salt wormwoods (*Artemisia* subg. *Seriphidium*), whereas *P. atropidicola* dwells on *Puccinellia* spp. (Poaceae), thus, they avoid acoustic interference.

Similar situation is observed in the species of *Diplocolenus* s.str. I failed to find any differences between the signals of three species studied (*D. bohemani* (Zetterstedt, 1840), *D. frauenfeldi* (Fieber, 1869) and *D. suttholli* Vilbaste, 1980) basing on available material. As in the cases discussed above, the shape of waves in a syllable (Figs 35–36 and 37–38, signals of

the same male are presented on oscillograms) as well as the outline of syllables and their duration (Figs 34–35, 37 and 39–46) provide no reliable diagnostic characters. All species are partly sympatric. The ranges of *D. bohemani* and *D. frauenfeldi* include Europe, Kazakhstan and Southern Siberia (possibly, with the exception of Eastern Transbaikalia). *D. suttholli* inhabits steppes of Mongolia and Southern Siberia (Tyva, Buryatia). These species were never found in the same biotope, however. For instance, in Buryatia *D. suttholli* was collected only on the meadows with steppe vegetation on the river banks, whereas *D. frauenfeldi* dwelled on the glades in dry pine forest on the slopes of the hills surrounding the valley (Table).

Therefore, the shape of waves in a signal, as well as the outline of syllable (slope of the leading and trailing edges, etc.) can vary greatly even within the same recording, especially if the singing insect changes its position from time to time (Figs 34–38). Consequently, differences of this kind revealed between two or three selected oscillograms do not give grounds for any taxonomic conclusions.

Duration of syllables is also rather variable. This parameter can vary by a factor of about 1.3–1.5 and more at constant temperature (Figs 47–48). In addition, it should be taken into account that under natural conditions temperature varies from place to place, even on a very small scale. As it was demonstrated by de Vrijer [1984], females of planthoppers respond remarkably well to playback of male calling signals at temperatures differing by 5°C from the male calling temperature. Thus, it is believed that comparison of signals recorded at temperatures differing within the range of 5°C is quite correct.

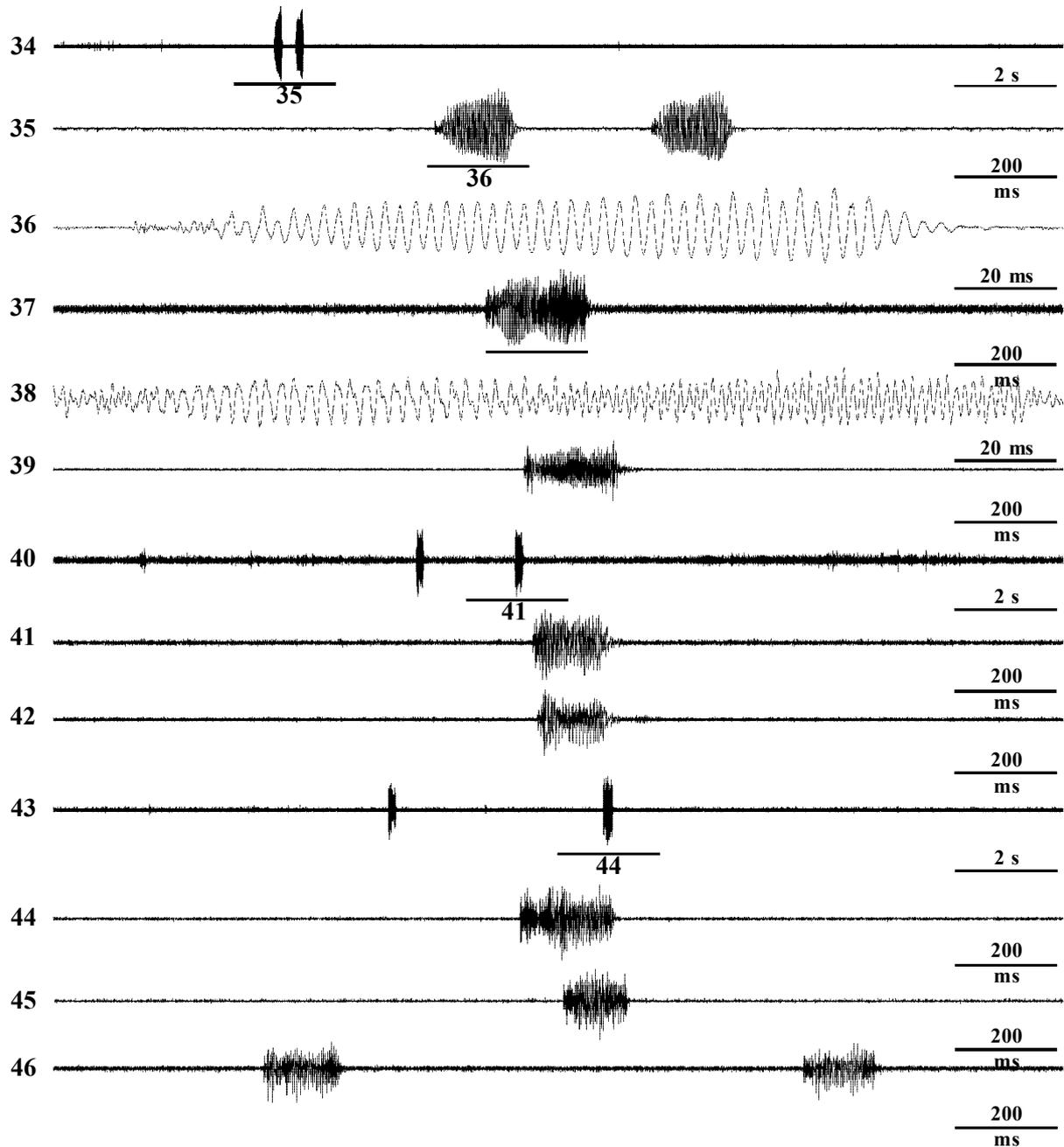
Although the ranges of variability of syllables duration in different species overlap considerably or even completely, statistical differences between samples exist almost always. In the present study Wilcoxon test was used for estimation of probability of identity of the samples presented on histograms on Figs 47–48. It was found that all samples including recordings of the same species from different localities differ significantly from each other. Consequently, in this case it is impossible to discriminate between species and intraspecific forms using statistical methods. Moreover, as a rule receptive female starts singing in reply to calling male almost immediately. So, even if it is granted that female possesses in the nervous system some mechanism capable of statistic analysis, it should hear considerable number of signals to obtain a sufficient sample prior to producing reply.

In certain cases species producing similar signals differ distinctly from each other in the shape of genitalia. The studied species of *Mocuellus* (Figs 49–50 and 51–52) and *Psammotettix* [Emelyanov, 1964] can be mentioned as an example. *D. bohemani* also differs from all congeneric species in these characters. Morphological differences between two other species of the genus and also, between *Sorhoanus medius* and *S.*

*hilaris* are not so clear (Figs 53–56 and 57–60). In such cases the use of acoustic analysis without considering the data on biology and distribution can lead to wrong taxonomic conclusions. Species not involved into acoustic interactions in nature due to differences in geographical distribution, host specialisation or ecological preference can produce signals indistinguishable in temporal pattern. Therefore, the similarity or even ab-

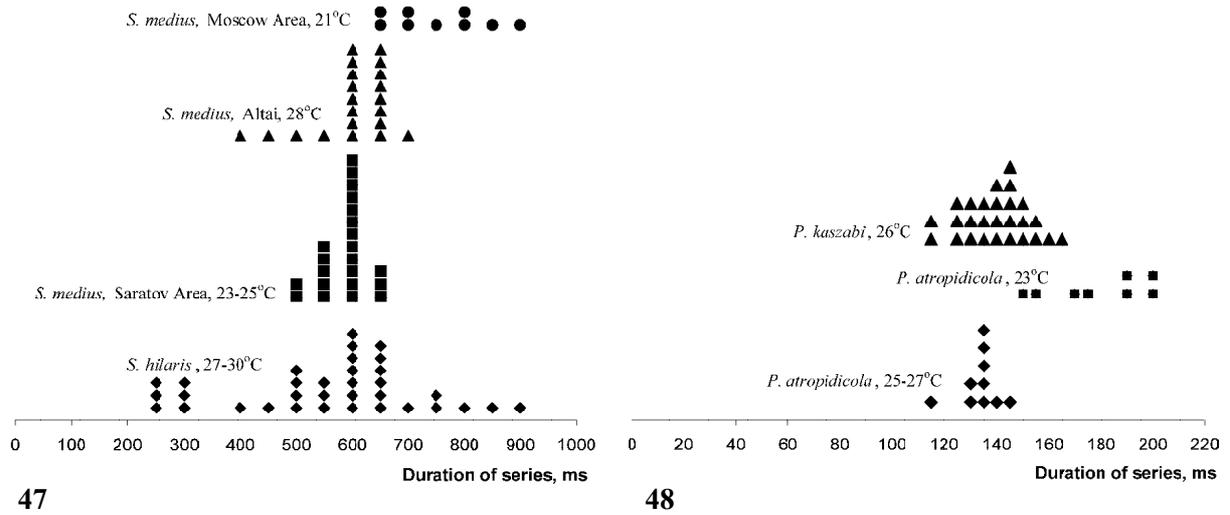
solute identity of structure of calling signals is not always unequivocal evidence of synonymy of the forms under investigation.

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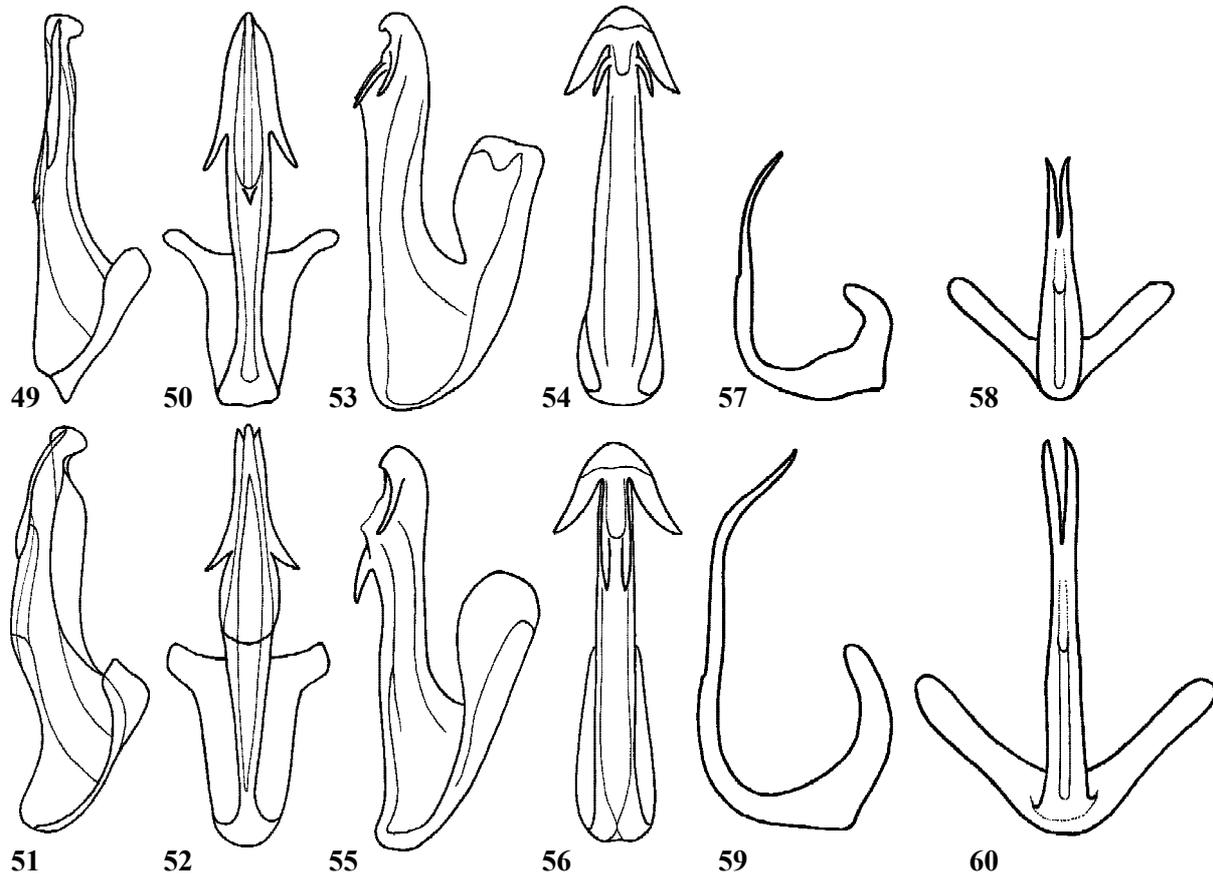
Figs 34–46. Oscillograms of calling signals of males: 34–39 — *Diplocoenus frauenfeldi*; 34–38 — from Saratov Area; 39 — from Buryatia; 40–42 — *D. suttholli*; 43–46 — *D. bohemani*, 43–44 — from Altai, 45–46 — from Moscow Area. Parts of signals indicated as 35–36, 38, 41 and 44 are given on oscillograms under the same numbers.

Рис. 34–46. Осциллограммы призывных сигналов самцов: 34–39 — *Diplocoenus frauenfeldi*; 34–38 — из Саратовской обл., 39 — из Бурятии; 40–42 — *D. suttholli*; 43–46 — *D. bohemani*; 43–44 — с Алтая, 45–46 — из Московской обл. Фрагменты сигналов, обозначенные цифрами 35–36, 38, 41 и 44 представлены на осциллограммах под такими же номерами.



Figs 47–48. Syllables duration in calling signals: 47 — *Sorboanus medius* and *S. hilaris*; 48 — *Psammotettix kaszabi* and *P. atropidicola*. Each point on histograms denotes duration of one syllable.

Рис. 47–48. Длительность серий в призывных сигналах: 47 — *Sorboanus medius* и *S. hilaris*; 48 — *Psammotettix kaszabi* и *P. atropidicola*. Каждая точка на гистограммах соответствует длительности одной серии



Figs 49–60. Penis: 49–50 — *Mocuellus collinus*; 51–52 — *M. angustiarum*; 53–54 — *Sorboanus medius*; 55–56 — *S. hilaris*; 57–58 — *Diplocolenus frauenfeldi*; 59–60 — *D. suttholli*; 49, 51, 53, 55, 57, 59 — lateral view; 50, 52, 54, 56, 58, 60 — back view.

Рис. 49–60. Пенис: 49–50 — *Mocuellus collinus*; 51–52 — *M. angustiarum*; 53–54 — *Sorboanus medius*; 55–56 — *S. hilaris*; 57–58 — *Diplocolenus frauenfeldi*; 59–60 — *D. suttholli*; 49, 51, 53, 55, 57, 59 — сбоку; 50, 52, 54, 56, 58, 60 — сзади.

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