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Acoustic Signals of Issidae (Homoptera, Cicadinea, Fulgoroidea) Compared with Signals of Some Other Fulgoroidea and Notes on Taxonomic Status of the Subfamily Caliscelinae

D. Yu. Tishechkin

Biological Faculty, Moscow State University, Moscow, 119899 Russia
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Abstract—Acoustic signals of nine Issidae species from the subfamilies Issinae and Caliscelinae have been investigated. The calling signals of Issinae are rather simple in their temporal pattern and consist of trains of uniform discrete pulses. In this subfamily, the territorial behavior and the related signals are poorly developed. In these characters Issinae are similar to the other Fulgoroidea studied, except Delphacidae. On the contrary, the calling signals of Caliscelinae are very complex and usually consist of several components with different temporal structures. Species of the genus *Ommatidiotus* (*O. dissimilis* and *O. inconspicuus*) show a well developed territorial behavior in both sexes and emit territorial and aggressive signals. These data confirm the hypothesis that Issinae and Caliscelinae are not closely related groups, and the latter should be considered a separate family.

The basis of the modern system of higher taxa in the family Issidae (Homoptera, Cicadinea, Fulgoroidea) was laid by Fennah's work (Fennah, 1954). More recently some genera were transferred by him (Fennah, 1984) from the family Issidae to the family Nogodinidae, tribe Bladinini, with the result that the dividing line between Issidae and Nogodinidae became somewhat indistinct; moreover the belonging of Bladinini to Nogodinidae rather than to Issidae is also disputed (Emel'yanov, 1990). In the same years it was suggested that the subfamily Caliscelinae (Hamilton, 1981) should be considered a separate family. At first, this idea received no comments in literature concerning planthoppers; however, recently it was supported by a group of specialists from Taiwan, who presented preliminary results of their work at the Ninth International Auchenorrhyncha Congress in Sydney in March 1997. In the first stage these entomologists conducted a comparative study of some separate morphological and biochemical features, including the structure of male genitalia, antennal sensory organs, and nucleotide sequences in two DNA segments in species belonging to different groups of Fulgoroidea. A particular system of Fulgoroidea families was constructed for each of them, and in many cases Caliscelinae were found to appear as a separate family on cladograms obtained (Cheng and Yang, 1997; Chang and Yang, 1997). I came to a similar conclusion, but by studying features of absolutely different nature, namely, acoustic signals. This work discusses the taxonomic interrelation between Issinae and Caliscelinae in view of bioacoustic facts. Some evidence on vibrational signals of specimens of five Fulgoroidea families were presented in one of my previous reports (Tishechkin, 1997), and here I only cite this work and do not reproduce most of oscillograms published there.

Vibrational signals were recorded using a GSP-311 crystal pick-up or the like and a cassette tape-recorder with a special amplifier. The list of species studied with mention of collection localities and air temperature during the sound-recording are shown in the table. The specimens whose signals were recorded are deposited in the collection of the Zoological Museum of Moscow State University. Signals were analyzed using an IBM PC AT equipped with an L–305 analog-digital converter produced by LCard Ltd (Russia). Five Issinae species from 5 genera and 6 Caliscelinae species from 3 genera were studied; oscillograms of signals obtained for some species belonging to other families of Fulgoroidea are presented for comparison.

Calling signals spontaneously produced by males ready to copulate have similar structures in different Issinae species. They all are rather simple in their temporal pattern and consist of trains of uniform short pulses separated by equal intervals or occurring in pairs (Fig.1, *1–11*). The signal duration usually does not exceed 2–3 s and only in *Agalmatium bilobum* Fieb. is as long as 10–15 s and even more (Fig. 1, *1–2*).

List of studied species of Issidae and other Fulgoroidea with mention of the collection locality and temperature during the sound-recording period

Species	Collection locality	Temperature during sound-recording period, °C
Family ISSIDAE		
Peltonotellus punctifrons Horv.	Rostov Province, Oblivskii Distr., near Sosnovii settl.	30–31
P. eous Kusn.	Environs of Almaty, steppe slopes of foothills of Zaili Alatau, high-grass	30
Peltonotellus sp.*	Environs of Almaty, steppe slopes of foothills of Zaili Alatau, high-grass	30
Caliscelis affinis Fieb.	1. Rostov Province, Oblivskii Distr., near Sosnovii settl., flood-lands of r. Chir	28
	2. Crimea, Kerch peninsula, Eastern shore of Kasantip bay, near Zolotoye settl. Grass along a saline river-bed in steppe	< 30
Ommatidiotus dissimilis Fall.	1. Moscow Province, Voskresensk Distr., near Belooserskii settl., upland swamp on lake bank, on cotton-grass	26–28
	2. Rostov Province, Oblivskii distr., near Sosnovii settl., on grass in steppe	31
O. inconspicuus Stål	Rostov Province, Oblivskii Distr., near Sosnovii settl., *Carex* along a sandy road	30–31
Agalmatium bilobium Fieb.	Kherson Province, Syvash, on wormwood in steppe	< 28
Alloscelis vittifrons Iv.	Rostov Province, Oblivskii Distr., near Sosnovii settl.	30–31
Scorlupaster asiaticum Leth.	Turkhmenia, near Dushak settl., on *Alhagi persarum*	30
Mycterodus intricatus Stål	Crimea, mountains near Glubokii Yar settl., N of Bakhchisaray	22–23
Scorlupella discolor Germ.	Crimea, mountains near Glubokii Yar settl., N of Bakhchisaray	22
Family CIXIIDAE		
Reptalus quinquecostatus Duf.	Crimea, mountains east of Pereval'noye settl. on the route Simferopol–Alushta	28–30
Family DELPHACIDAE		
Dicranotropis hamata Boh.	Moscow Province, near Pirogovo	23–25
Metropis mayri Fieb.	Moscow Province, Serpukhov distr., flood-lands of Oka River near Luzhki vil.	20–21
Family DERBIDAE		
Malenia sarmatica Anufr.	Near Aderbyevka settl., 6–7 km E of Gelendzhik, flood-lands of Aderbyevka River, on *Salix elbursensis*	27–30
Family DICTYOPHARIDAE		
Mesorgerius tschujensis Vilb.	Southern Tuva, near Ersin settl., in steppe on *Artemisia frigida*	24

* A new species to be described by A.F. Emel'yanov.

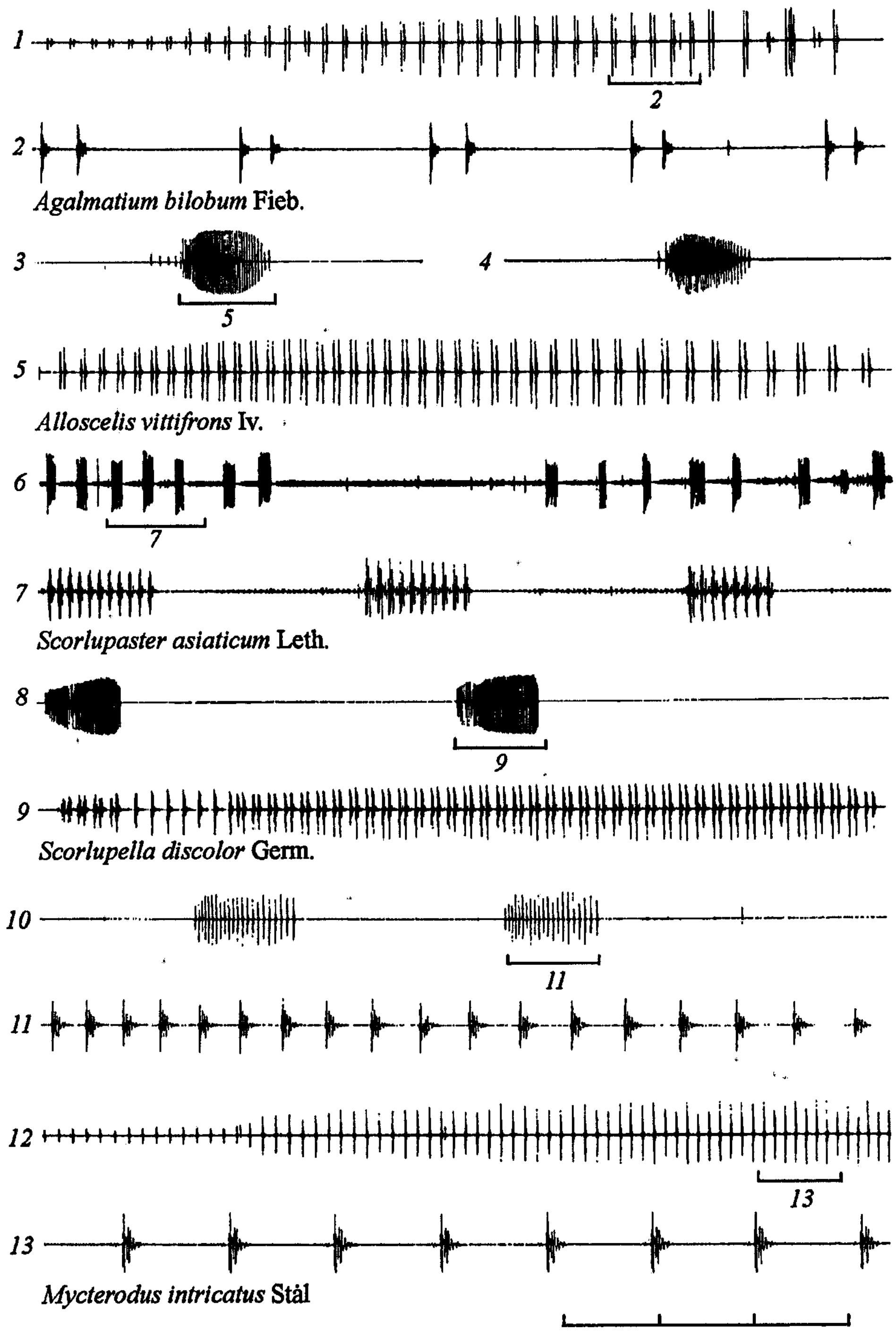

Fig. 1. Acoustic signals of Issinae species.(*1–11*) Calling signals, (*12–13*) territorial signals. The fragments of signals designated as *2, 5, 7, 9, 11, 13* are shown at higher sweep rate on oscillograms with corresponding numbers. Scale: *1, 3, 4, 6, 8, 10, 12*—2 s, *2, 5, 7, 9, 11, 13*—200 ms.

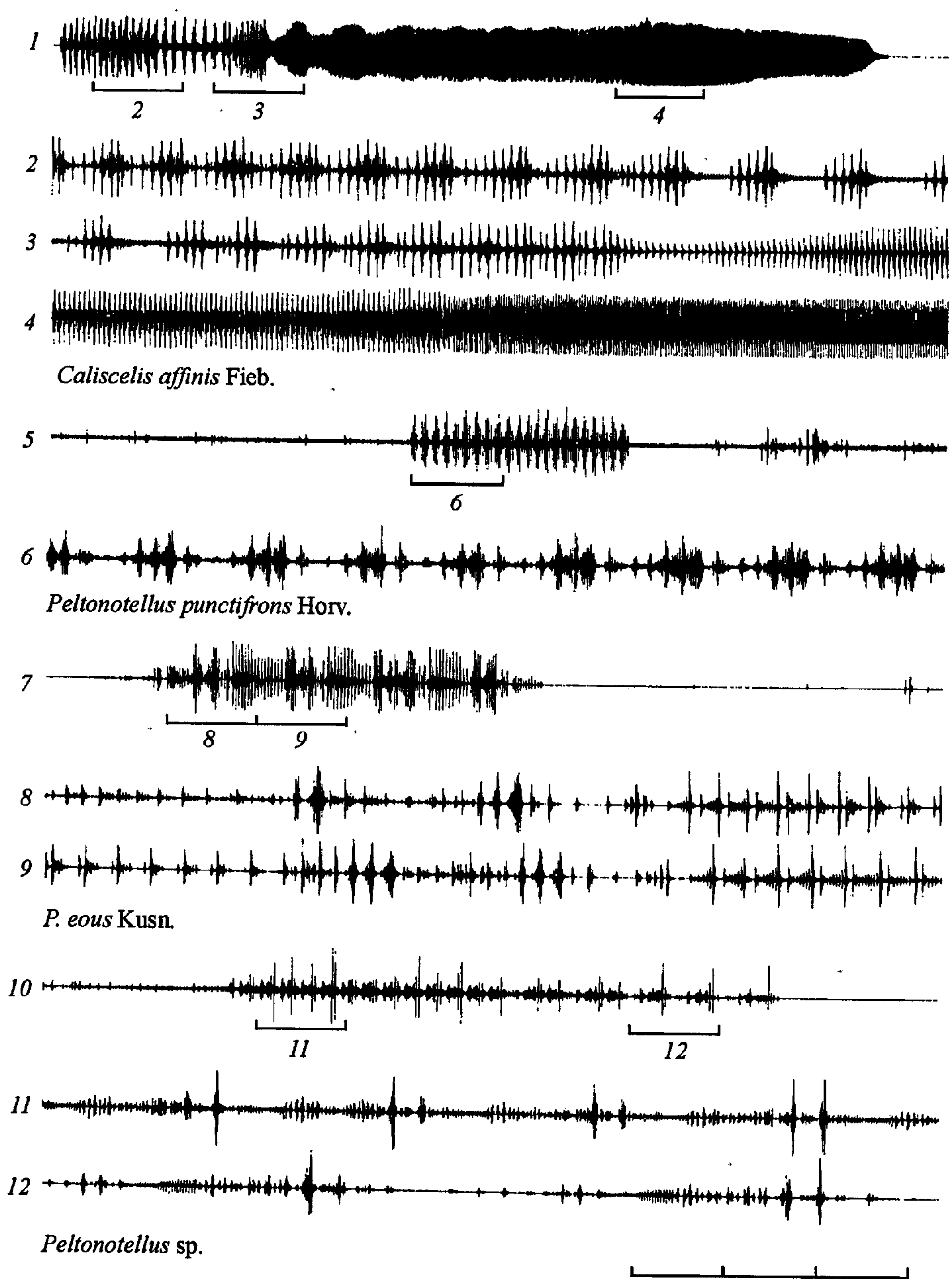

Fig. 2. Calling signals of Caliscelinae species. The fragments of signals designated as *2–4, 6, 8–9, 11–12* are shown at higher sweep rate on oscillograms with corresponding numbers. Scale: *1, 5, 7, 10*—2 s, *2–4, 6, 8–9, 11–12*—200 ms.

Several Issinae males placed in the same cage ignore each other; however, if one of them emits a calling signal, the other males begin singing, too, and signals produced during such call-over differ in no way from the typical calling ones. A similar situation was observed in *A. bilobum*, *Scorlupaster asiaticum* Leth. and *Scorlupella discolor* Germ., whereas in *Alloscelis vittifrons* Iv. and *Mycterodus intricatus* Stål only signals of single males were recorded. In the last species long trills with strongly varying pulse repetition period

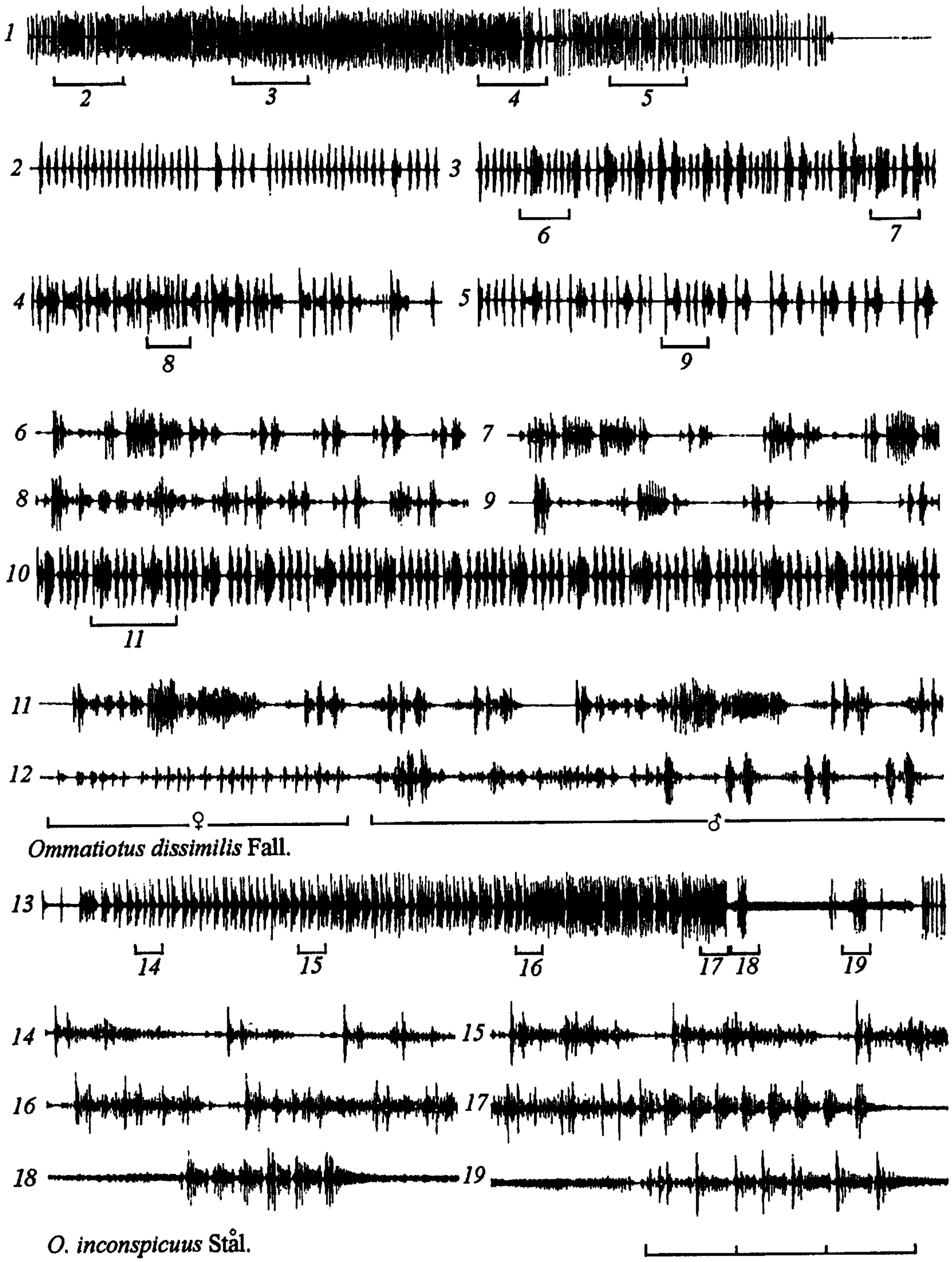

Fig. 3. Acoustic signals of specimens belonging to the genus *Ommatidiotus*. (*1–11, 13–19*) Calling signals, (*12*) the male calling signal and the female responding signal. The fragments of signals designated as *2–9, 11, 14–19* are shown at higher sweep rate on oscillograms with corresponding numbers. Scale: *1*—12 s, *13*—4 s, *2-5, 10*—2 s, *6-9, 11-12, 14-19*—200 ms; (*1-9*) calling signal of a male *O. dissimilis* from Rostov Province, (*10–11*) signal of a male from environs of Moscow.

were recorded, produced spontaneously together with a call (Fig. 1, *12–13*). Such signals can be considered territorial ones; however, additional experiments are needed to make the final decision on this question.

Calling signals of Caliscelinae are usually much more complex in their amplitude-temporal pattern, and the signal duration reaches several tens of seconds or even 2–3 min (Figs. 2–3). In the simplest case—in

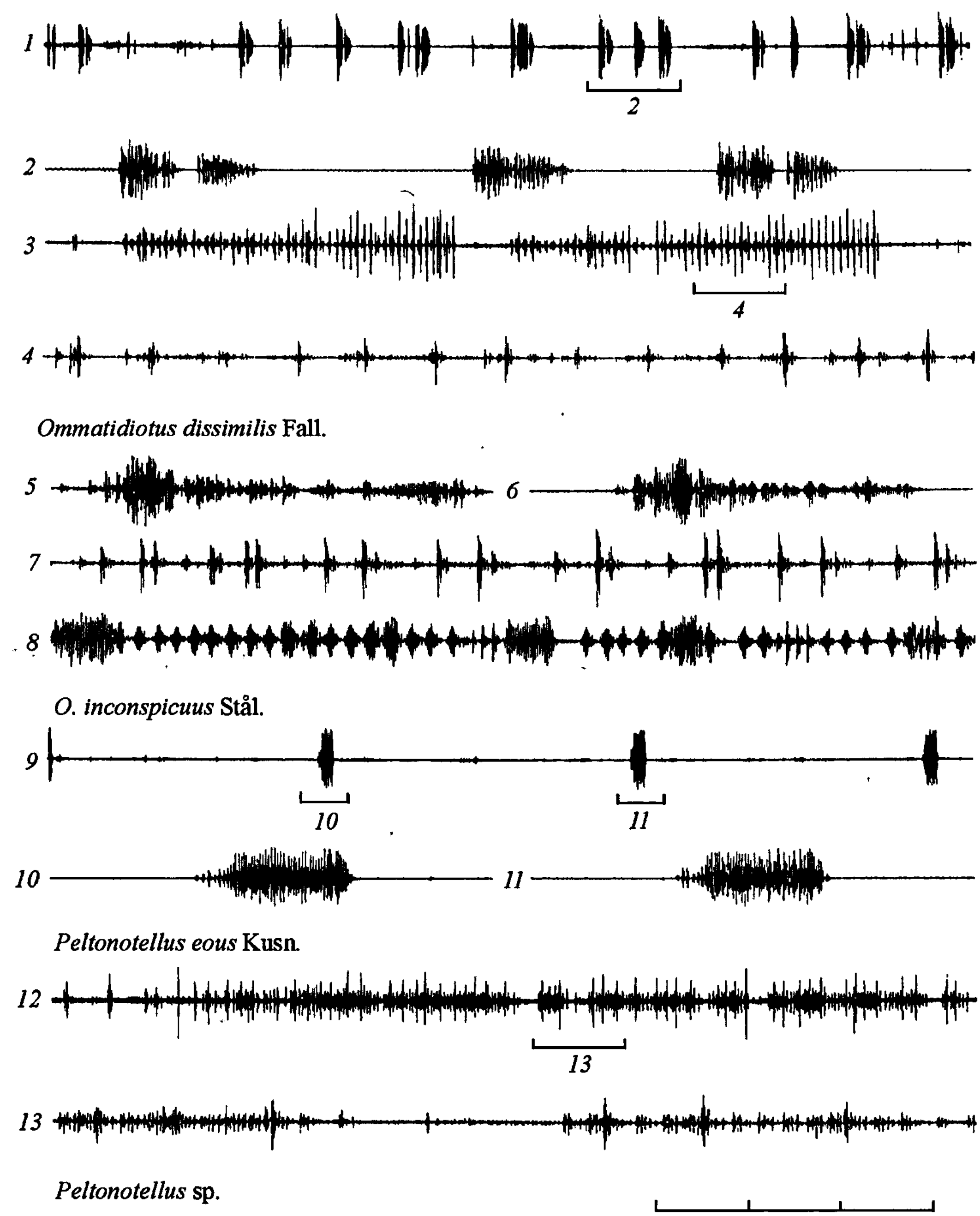

Fig. 4. Acoustic signals of Caliscelinae species. (*1–2, 5–6, 9–13*) Male territorial signals, (*3–4, 7*) female territorial signals, (*8*) the male aggressive signal. The fragments of signals designated as *2, 4, 10–11, 13* are shown at higher sweep rate on oscillograms with corresponding numbers. Scale: *1, 3, 9, 12*—2 s, *2, 4–8, 10–11, 13*—200 ms.

Peltonotellus punctifrons Horv. (Fig. 2, *5–6*) and sometimes in *Ommatidiotus dissimilis* Fall. (Fig 3, *10–11*)—signals consist of series, i.e., recurrent groups of pulses of uniform temporal pattern (commonly termed "chirps" in the English-language literature) (see, e.g., de Vrijer, 1986). More often the following situations are observed: either there occurs a regular change (not always clearly pronounced) of the series structure from the beginning to the end of a song (Figs. 2, *7–12*; 3, *1–9*), or fragments with different temporal pattern are present in the same signal (Figs. 2, *1–4*; 3, *13–19*). It is of interest that similar signals consisting of several components, sometimes have the same pattern in different species. For example, in *Caliscelis affinis* Fieb. and *Ommatidiotus inconspicuus* Stål the first part of the signal consists of rather complex series with slightly varying structure (Figs. 2, 2–3 and 3, 14–17), while the second one is a long monotonous fragment (Figs. 2, 4 and 3, 18-19), although in *O. inconspicuus* short impulses from the first part are occasionally present in the second one. In *C. affinis* the shape of oscillations changes dramatically at a certain moment. This can be seen in oscillogram at high sweep rate (Figs. 2–4) and recognized aurally as increase in carrier frequency of the signal.

No territorial signals were recorded in males of *C. affinis* and *P. punctifrons* staying together on the same plant, although, similarly to Issinae the song of a male stimulated the acoustic activity of the others. On the other hand, single males of *P. eous* Kusn. and *Peltonotellus* sp. also emitted at irregular intervals signals of different type and less stable structure, which should apparently be considered territorial signals (Fig. 4, *9–13*).

Unlike other studied Issidae, species of the genus *Ommatidiotus* show well developed territorial behavior in both males and females, which is untypical of planthoppers on the whole; when isolated, specimens of both sexes occasionally emit territorial signals (Fig. 4, *1–7*); some insects staying on the same plant sing much more actively, nearly always calling one another. When two individuals come together, the intensity of such call-over reaches a maximum, sometimes attacks and attempts to drive away the enemy from the stem take place after that. In addition, in *O. inconspicuus*, trills of pulses different from territorial signals were recorded in the most conflicting situations. These signals are considered to be aggressive (Fig. 4, *8*).

Ommatidiotus males most likely sing using tymbal organs and differ in no way from the majority of Cicadinea in this respect. The manner in which females produce territorial signals is quite original. A singing female presses its abdomen end against the substratum, at this instant the inner gonapophyses of her ovipositor work in the same way as during oviposition, making out-of-phase longitudinal saw-like movements. These movements are well noticeable even under six-seven-fold magnification and are undoubtedly directly related to the sound-producing process, because their rhythm coincides with the pulse repetition period. Such a sound-producing apparatus has been discovered in planthoppers for the first time, and, although the mechanism of their work is not clear enough, it can be identified as a stridulative one.

The search for sexual partner was observed only in *O. dissimilis*. The system of sexual communication in this species was found to be constructed in the same way as in other Fulgoroidea studied in this respect (see, e.g., Strubing, 1977, de Vrijer, 1986). In the first stage a male emits calling signals spontaneously and a receiving female answers him. After that insects start to sing in turn, with the female staying at the same place, and the male moves over the plant in different directions until finding the female, and then copulation takes place. Response signals of the female are short trills of pulses varying in temporal parameters (Fig. 3, *12*), and in this connection they seem to be unimportant for identification of a conspecific individual, serving solely for attracting and orientating a singing male.

It is not yet known whether the female emits responding and territorial signals by the same sound-producing apparatus or uses different mechanisms. Judging from the structure of signals the latter seems to be more likely.

According to bioacoustic features, all the Issidae studied can be divided into two natural groups: Issinae and Caliscelinae. The former, as noted above, emit calling signals with rather simple structure (Fig. 1), whereas in the second group the amplitude-temporal pattern of signals is much more complex.(Figs. 2–3). It is necessary to note that signals produced by *Alloscelis vittifrons* indicate beyond doubt that this species belongs to Issinae, in spite of Kusnezov's opinion (Kusnezov, 1930) who erroneously referred it to Caliscelinae. Both Nast (1972) and Fennah (1987) overlooked this error, although already in "A Key to Insects from the European Part of the USSR" (Emel'yanov, 1964) the genus *Alloscelis* was referred to Issinae.[1] Specimens of the genus *Ommatidiotus* are distinguished among Caliscelinae, by their pronounced territorial behavior contrasting with that in *C. affinis* and species of the genus *Peltonotellus*, where it may be poorly developed. The isolation of *Ommatidiotus* from other Caliscelinae conforms to the fact that the genus *Ommatidiotus* belongs to the tribe Ommatidiotini (=Augilini) while *Caliscelis* and *Peltonotellus*—to Caliscelini (Fennah, 1987). Nonetheless, unification of these two groups, i.e., *Caliscelis* + *Aphelonema* and *Omma-*

[1] Moreover, in my previous work (Tishechkin, 1997) an error was made in the legend to the last figure. One should read *Alloscelis vittifrons* instead of *Scorlupaster asiaticus* and vice versa. In the present work this error was corrected (Fig. 1).

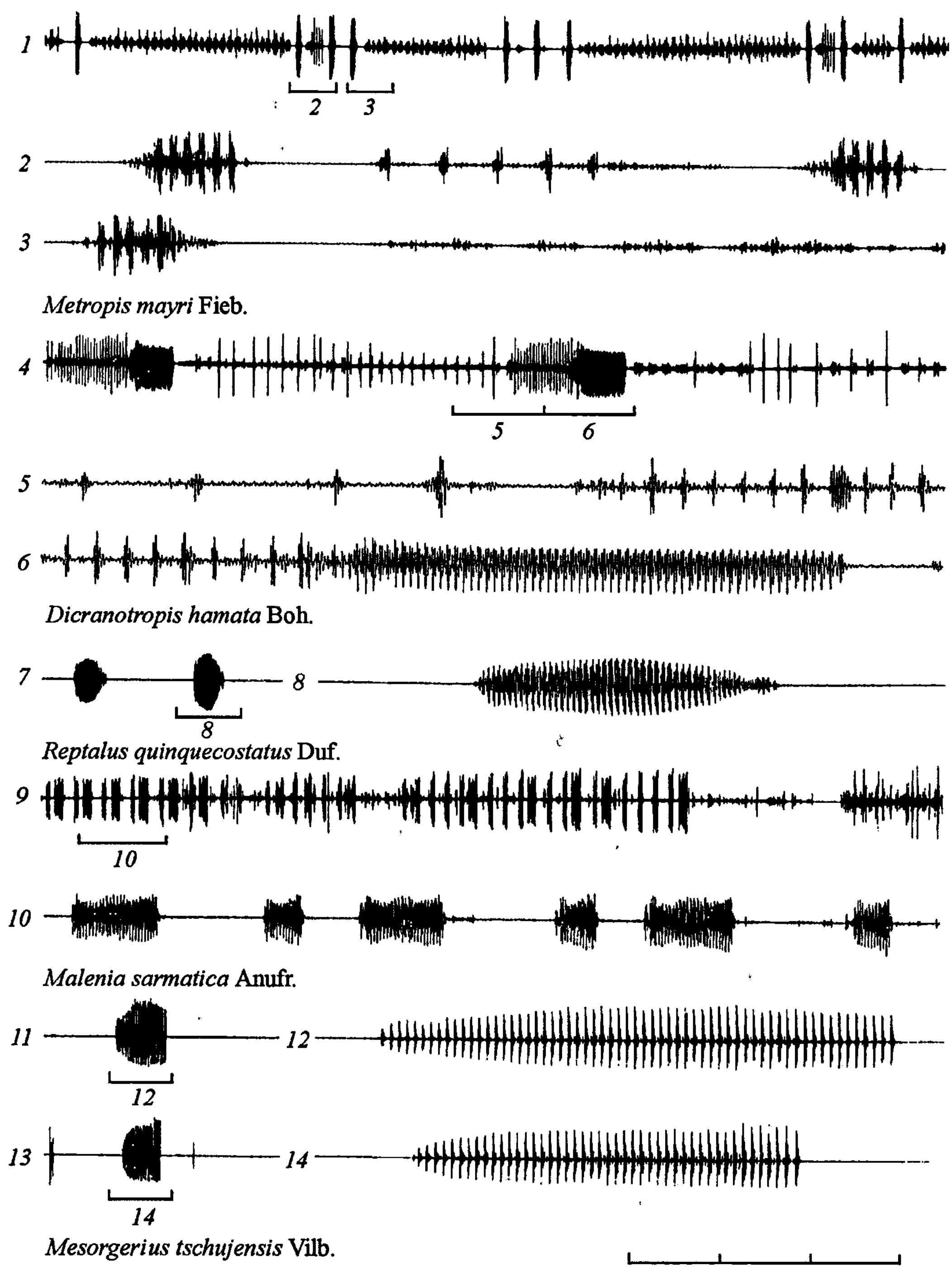

Fig. 5. Acoustic signals of Fulgoroidea species. The fragments of signals designated as *2–3, 5–6, 8, 10, 12, 14* are shown at higher sweep rate on oscillograms with corresponding numbers. Scale: *1*—4 s; *4, 7, 9, 11, 13*—2 ms; *2–3., 5–6, 8, 10, 12, 14*—200 ms.

tidiotus, in the common subfamily Caliscelinae seems to be correct, because the similarity of the calling signal structure in *C. affinis* and *O. inconspicuus* indicates that they are closely related. Since the signals of these species have rather complex amplitude-temporal structure it seems unlikely that they had emerged in specimens of the different genera convergently. The temporal pattern of the calling signal of *O. dissimilis* is very similar to that of *O. inconspicuus* (Fig. 3, *1* and *13*); however, it has no second (monotonous) part, which, probably, has been lost for the second time. It is not improbable that the rather simple song of

P. punctifrons had also developed as a result of reduction of some components in the primordially more complex signal.

The phylogenetic closeness of Caliscelinae and Issinae is not confirmed by bioacoustic evidence. The overwhelming majority of Fulgoroidea, both archaic species and rather advanced ones, produce calling signals which are similar to those of Issinae. This group includes Cixiidae, Derbidae, Dictyopharidae (both Dictyopharinae and Orgeriinae), and Tropiduchidae. A set of oscillograms of some species belonging to these families was presented in one of my earlier works (Tishechkin, 1997), in addition, some previously unpublished oscillograms are shown in Fig. 5, *7–14*. The only exception among Fulgoroidea are Delphacidae, because their signals usually consist of several components and can be compared with complex signals of Caliscelinae (Fig. 5, *1–6*). Similarly to *Ommatidiotus* belonging to Caliscelinae Delphacidae exhibit a pronounced territorial behavior and produce signals of the corresponding types (Ichkawa, 1982).

Thus, according to the bioacoustic evidence obtained, Issinae can be united with the majority of families Fulgoroidea and opposed to Caliscelinae. Therefore, there seems to be no reason to include the latter into Issidae, while raising them to a rank of a separate family appears to be correct. On the other hand, if the given taxonomic rearrangement is taken into account, Caliscelinae, or, more exactly, Caliscelidae, show a significant similarity with Delphacidae, although it is difficult to tell as yet whether it is a symptom of relationship or a result of a convergence.

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