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The structure of voice signals of Siberian chipmunk (*Tamias sibiricus* Laxmann 1769; Rodentia: Sciuridae)

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ABSTRACT. The vocalizations of Siberian chipmunks recorded under natural conditions were studied. Variation of time-and-frequency structure was described. The structure of studied Siberian chipmunks calls was different from the structure of American chipmunks calls, so as from the calls of specimens from introduced population of Siberian chipmunk in Freiburg (Germany).

KEY WORDS: Siberian chipmunk, *Tamias sibiricus*, vocalization.

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Структура голосовых сигналов сибирского бурундука (*Tamias sibiricus* Laxmann 1769; Rodentia: Sciuridae)

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РЕЗЮМЕ. Изучены звуковые сигналы сибирских бурундуков, записанные в природе. Описаны их частотно-временная структура, изменчивость. Показано, что структура криков сибирских бурундуков значительно отличается от структуры криков других видов этого рода, а также от структуры криков зверьков из интродуцированной популяции г. Фрайбург (Германия).

КЛЮЧЕВЫЕ СЛОВА: Бурундук, *Tamias sibiricus*, вокализация.

Introduction

During the last few decades the bioacoustical studies were quite popular. However, the vocalizations of Siberian chipmunk (*Tamias sibiricus* Laxmann, 1769) have not been described. The information on this species is incomplete and limited to a brief description of calls from introduced population in Europe (Smit, 1976; Geinitz, 1982) and description of estrous calls (Blake, 1992).

However, there has been no information on the structure and variation of the calls in the native range of Siberian chipmunks.

This study describes the structure and variation of distant calls of *Tamias sibiricus*. Despite of the popular stories about "whistiling" Siberian chipmunk and hunter's fairy tales about chipmunks "crying before the rain", the records of the vocalizations in this species are rare. During fourteen years of studying mammalian vocalizations in Taiga regions (see Lissovsky, 2005) we were able to record only a rather modest collection of chipmunk calls. Moreover, we could not find any records of chipmunk' calls in sound libraries of Russia and the US, except for the B.N. Veprintsev Phonotheca of Animal Voices.

Material and Methods

One hundred ninety eight vocalizations from 35 free-ranging chipmunks and one captive individual were collected in 19 localities. Localities (samples) and number of calls/number of specimens are listed below. Two types of calls were described, and they will be referred to as "chips" and "chucks" here. Such nomenclature is consistent with the previous studies done on North American (Brand, 1970; Dunford & Davis, 1975). However, it should be noted that calls of Siberian chipmunks are very different and sound more as whistles and gurgles.

Chips: Russia, Moscow region, Ruzskiy district, near Porechye village (probably introduced) (2/1); Vicinities of Tomsk (7/2); Altayskiy kray, Charyshskoe district, Tigeretskiy Range, upper Inya river (3/1); Krasnoyarskiy kray, Kuragino district, Manskoe Belogorye Range, station Krol (1/1); Krasnoyarskiy kray, Ermakovskoe district, Oyskiy Range, Ergaki Range, vicinities of Olenya Rechka shelter (8/3); Krasnoyarskiy kray, Turukhansk district, biological station "Mirnoe" (11/2); Irkutsk region, Ust-Kut district, 11 km S from Ust-Kut (5/1); Irkutsk region, Verholenskiy district, Baikalskiy Range, upper Lena river (2/1); Irkutsk region, Zhigalovo district, Ilga river (3/2); Buryatia Republic, Severobaikalsk district, Barguzinskiy Range, Sosnovka river valley (7/4); Chita region, Sretensk district, right bank of Shilka river, near Ust-Chernaya village (3/2); Chita region, Sretensk district, right tributary of Shilka river — Uleygicha river (4/1); Chita region, Sretensk district, right tributary of Shilka river — Chachakan

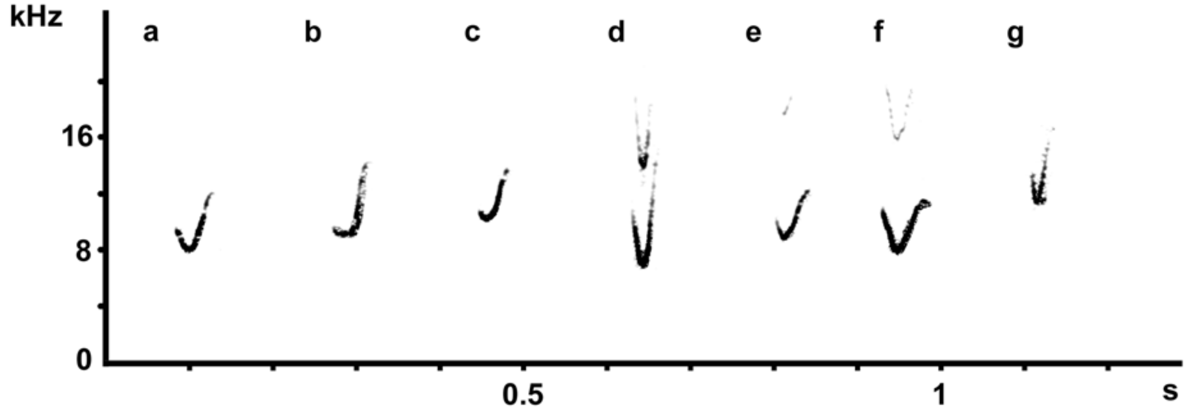

Figure 1. Examples of sonograms of chip calls of *T. sibiricus*.
A — from Tomsk; B — from Baikalskii Range; C — from Ust-Chernaya village; D — from Uleygicha River; E and F — from Balin station; G — from Lazovsky reserve.

river (6/1); Chita region, Alexandro-zavod district, Kher-khira river (7/1); Chita region, Kalga district, Kozlovo village (1/1); Primorskiy kray, Lazo district, Lazovsky state nature reserve (15/3); China, Inner Mongolia, Great Khingan Range, Holesu village (1/1); China, Inner Mongolia, Great Khingan Range, Balin station (14/1).

Chucks: Krasnoyarskiy kray, Kuragino district, Manskoe Belogorye Range, station Krol (6/1); Chita region, Sretensk district, right tributary of Shilka river — Chachakan river (19/2); Primorskiy kray, Luchegorsk district, Bikin river (8/1); Primorskiy kray, Lazo district, Lazovsky state nature reserve (27/2); captive specimen in 4-th generation originated from Altai Mountains (25/1).

Calls were analyzed in Syrinx sound analysis program (John Burt, www.syrinxpc.com) and Spectra Lab FFT Spectral Analysis System, version 4.32.11 (1995–1998). For the analysis recordings were digitized with Sound Forge v. 4.5 on EgoSys WaveTerminal v. 3.85 at 44,100 Hz. For chucking calls we used additional digitizing at 8,000 Hz.

The following measurements were taken for each call: signal duration (t), minimum (Fmin), and maximum (Fmax) frequencies. Twenty frequency measurements (F1–F20) were sampled over 1/19 interval of the signal duration.

Variation of the shape of frequency modulation curve was studied in the "Principal Components and Classification analysis" module of Statistica 6.0 (StatSoft 2001), with F1–F19 taken as variables. F20 was excluded from analysis because of lack of variance. Differences between samples were calculated using "ANOVA" module of Statistica 6.0 (StatSoft 2001).

Vocalization recordings 1, 3–8, 10–20, 22, and 23 were obtained from the sound library of Zoological museum of Moscow State University. Recordings 2, 9, and 21 were loaned from B.N. Veprintsev Phonotheca of Animal Voices, Institute of Theoretical and Experimental Biophysics of RAS, Puschino.

Results

Two types of calls (chips and chucks) were identified for Siberian chipmunks under natural conditions.

Chip vocalization consisted of a single short call or a series of short calls separated by the time interval of 1.97–8.55 s (4.20±0.24 s; y=1.87; n=60). These calls were produced when animals encountered a novel object and appeared to be agitated or curious. Also, when chipmunks saw a human, they took cover in some temporary shelter and chipped from there. If the observer remained quiet and motionless, chipmunks would continue to chip up to four minutes or even more. However, if the observer tried to approach, chipmunks would become silent or would emit a single call before escaping.

Chips of Siberian chipmunk have V- or U-shaped frequency modulation curves (Fig. 1). Descending branch of modulation curve is often partly reduced. The call starts at 6.51–15.91 kHz (9.98±0.13 kHz; y=1.39; n=113), then its frequency decreases to 5.82–11.75 kHz (8.67±0.14 kHz; y=1.44; n=113), and afterward frequency increases up to its maximum value of 8.78–15.94 kHz (11.77±0.14 kHz; y=1.45; n=113). Signal duration is 14–56 ms (35±0.8 ms; y=8.8; n=113). Geographical samples are significantly different in all measured parameters (F=3,74 p<0,01).

The pattern of chip calls is best described by using principle components analysis. The first two principle components (81% of total variance) reflect the general shape of frequency modulation curves corresponding to the degree of symmetry of branches of the curves (Fig. 2). Only "symmetric" calls were recorded on Ilga River, biological station Mirnoe, Porechie village, Uleygicha River. Single "symmetric" calls were recorded on Tigeretskii Range, (17%), Ust-Chernaya village (33%), Kher-khira River (14%), Chachakan River (17%), Balin station (36%), and in Lazovsky reserve (7%).

The third and the fourth principle components (14% of total variance) are poorly correlated with initial vari-

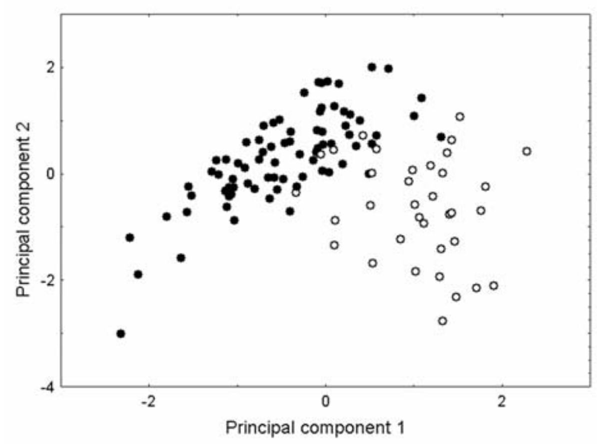

Figure 2. Distribution of *T. sibiricus* calls in the space of the principal components axes. Open circles show calls with “symmetric” shape of frequency modulation curve (frequency diapason of descending branch is more than a half of frequency diapason of ascending branch); closed circles show “asymmetric” calls (frequency diapason of descending branch is less than a half of frequency diapason of ascending branch).

ables (Tab. 1) and do not significantly correlate with longitude and latitude of recording localities. Variation in calls’ time-and-frequency parameters is depicted in Fig. 3.

Table 1. Correlation of first four principal components (PC), explaining 95% of variation of frequency modulation curve of *T. sibiricus* calls, and variables, included in analysis.

	PC 1	PC 2	PC 3	PC 4
F1	0.75	-0.51	0.23	-0.21
F2	0.78	-0.50	0.25	-0.19
F3	0.80	-0.51	0.23	-0.17
F4	0.81	-0.51	0.21	-0.13
F5	0.80	-0.54	0.16	-0.06
F6	0.76	-0.60	0.02	0.07
F7	0.63	-0.68	-0.18	0.24
F8	0.21	-0.72	-0.54	0.34
F9	-0.46	-0.61	-0.60	0.12
F10	-0.76	-0.45	-0.40	-0.12
F11	-0.85	-0.37	-0.22	-0.26
F12	-0.87	-0.35	-0.10	-0.27
F13	-0.90	-0.32	0.01	-0.24
F14	-0.90	-0.31	0.10	-0.18
F15	-0.89	-0.32	0.23	-0.07
F16	-0.88	-0.33	0.30	0.04
F17	-0.85	-0.31	0.36	0.14
F18	-0.79	-0.30	0.41	0.27
F19	-0.59	-0.33	0.49	0.41

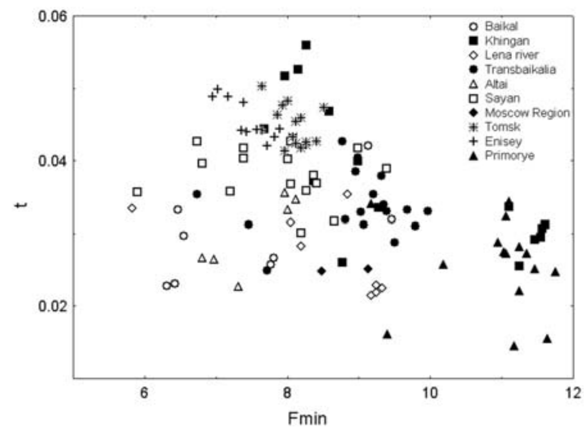

Figure 3. Distribution of *T. sibiricus* calls in the space of minimum frequency (Fmin, kHz) and call duration (t, s) axes.

Chucks is a series of low-frequency calls, which are producing in the moments of extreme agitation and irritation. Each call has a harmonic structure (Fig. 4) and consists of one to three, but usually two (55%) short unmodulated in frequency signals. The first signal of each call is produced within frequency diapason of 1.1–1.3 kHz and lasts approximately 0.06–0.08 s (n=40). The frequency slightly increases (~ 0.1 kHz) by the end of the signal in calls produced by chipmunks from Altai, Sayan Mountains, and Transbaikalian regions. Such phenomenon is not found in vocalizations of animals from Primorskii territory. The second signal of each call is shorter (0.03–0.06 s; n=20) and lower in frequency (1.0–1.2 kHz; n=20). If the third signal is present, it is even shorter and lower in frequency (0.03 s; 1.1 kHz; n=3).

Discussion

Chips. The shape of frequency modulation curves did not demonstrate correlation with geographical location of samples (Fig. 5). Distribution of “symmetric” and “asymmetric” calls in the geographical space demonstrated no clear pattern as well. On the other hand, the parameters of time-and-frequency diapason showed some correlation with geographical position of samples (Fig. 6). Calls from Primorskii Territory and Khingan had higher minimum frequency, while calls from the west tended to be lower in minimum frequency. However, it should be noted that variation of this parameter in the sample from Khingan was relatively high (Fig. 3).

Chucks. It is premature to discuss geographical variation for chucking calls. Most probably, we should acknowledge that structure of this type of calls is conservative. In contrast to chip calls, frequency range was very constant in chucking calls. The lack of frequency increase in chucking calls from Primorskii Territory should be confirmed by additional sampling.

Interestingly, sonograms of the *T. sibiricus* calls

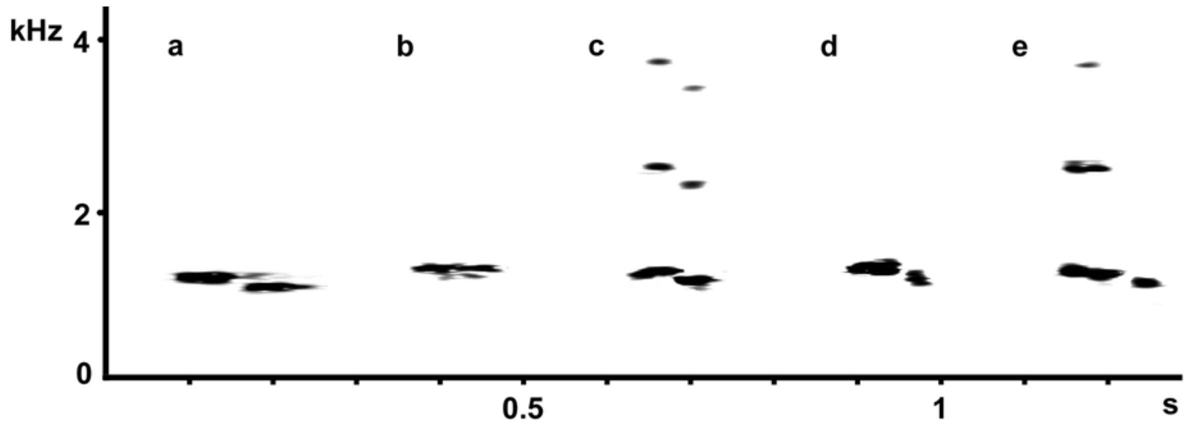

Figure 4. Examples of sonograms of chuck calls of *T. sibiricus*.
A — from Bikin River; B — from Lazovskii reserve; C — from Chachakan River; D — from Krol station; E — captive specimen from Altai Mountains.

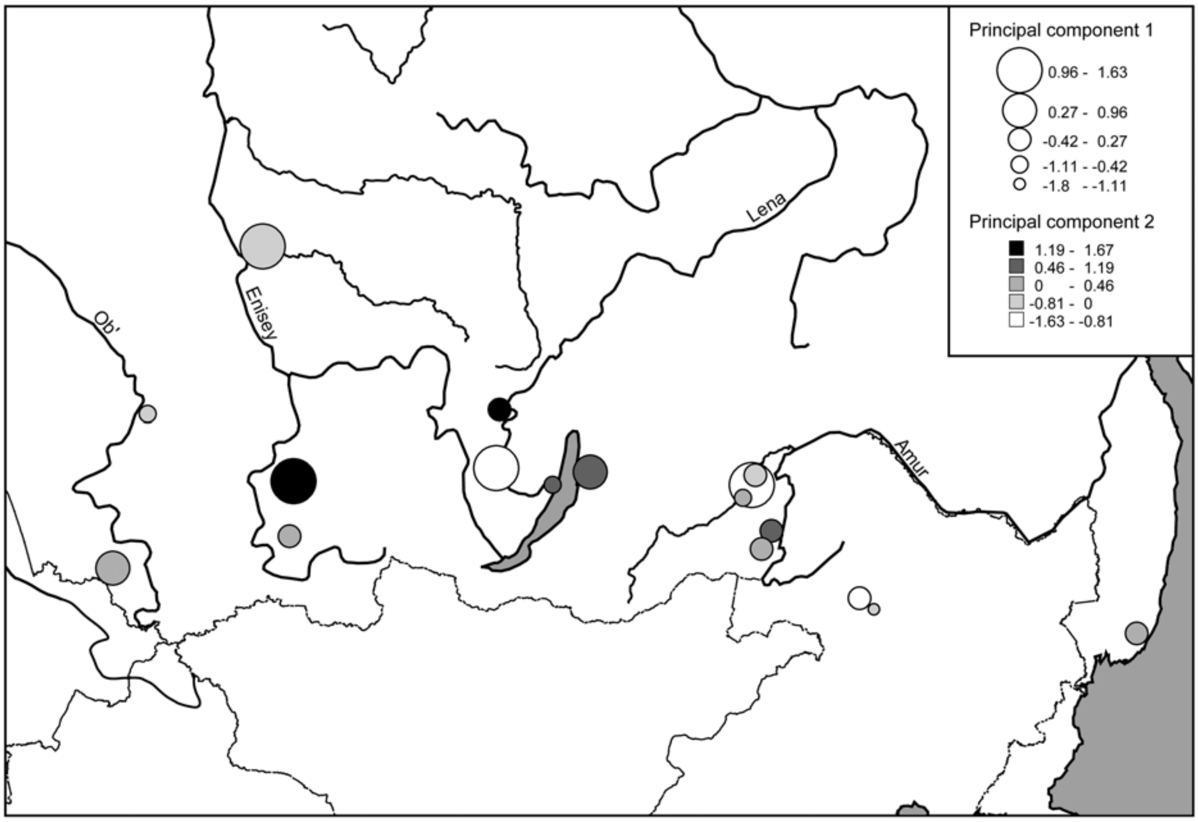

Figure 5. Geographical variation in the shape of frequency modulation curve of *T. sibiricus* calls, reflecting in the two first principal components. Size and gradation of grey of each circle correspond to average values of principal components in geographical samples.

described in this study were very different from the ones obtained previously by Geinitz (1982). Geinitz described calls of chipmunks from introduced population in Freiburg (Germany). The chip vocalizations were defined as high (12–14.5 kHz), unmodulated in frequency signals (Fig. 7G). In addition, chipmunks from this population produced another type of calls featured by deep frequency modulation (Fig. 7F). Freiburg chipmunks produced these calls with short (about 0.3 s) and constant time period. However, we did not register such organized series of calls during our observations.

Recordings from North American chipmunks showed very different shape of frequency modulation curves of chips (Dunford & Davis, 1975; Gannon & Lawlor, 1989; Silva *et al*., 1994). These calls had more of an

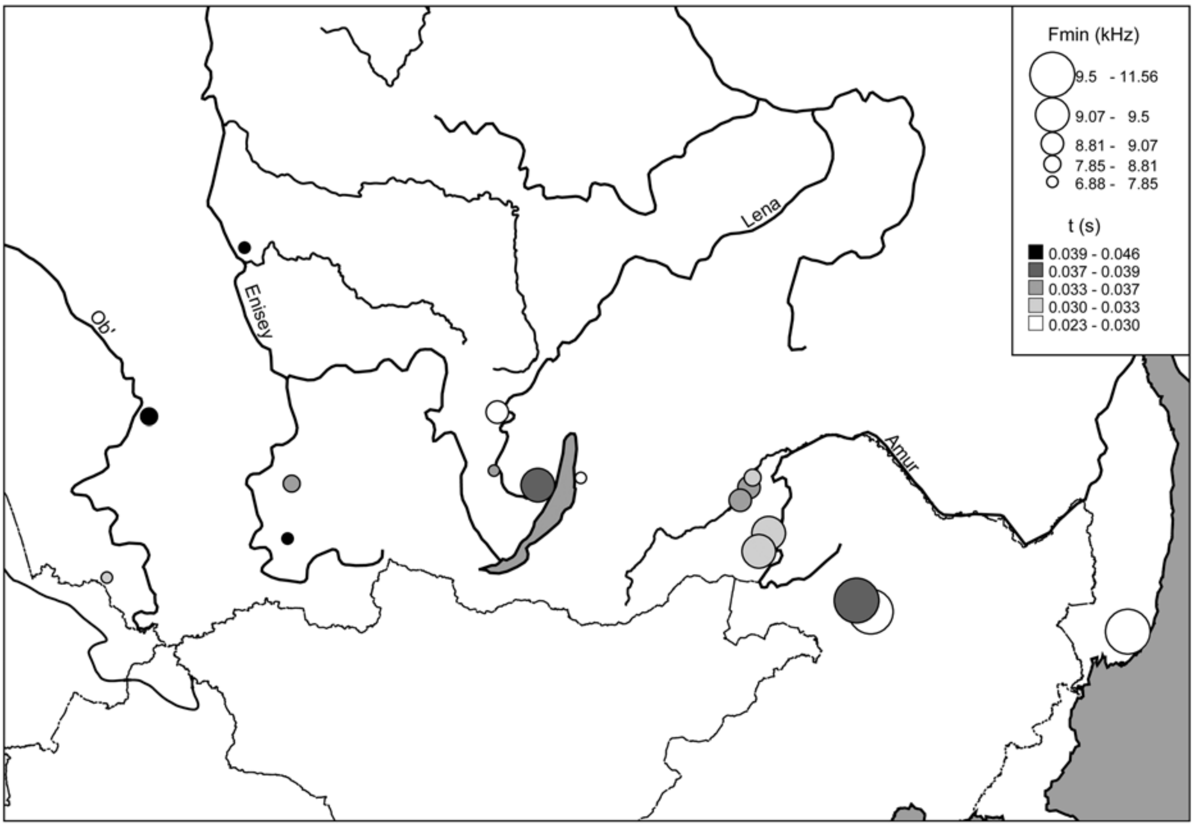

Figure 6. Geographical variation in minimum frequency (Fmin, kHz) and duration (t, s) of *T. sibiricus* calls. Size and gradation of grey of each circle correspond to average values in geographical samples.

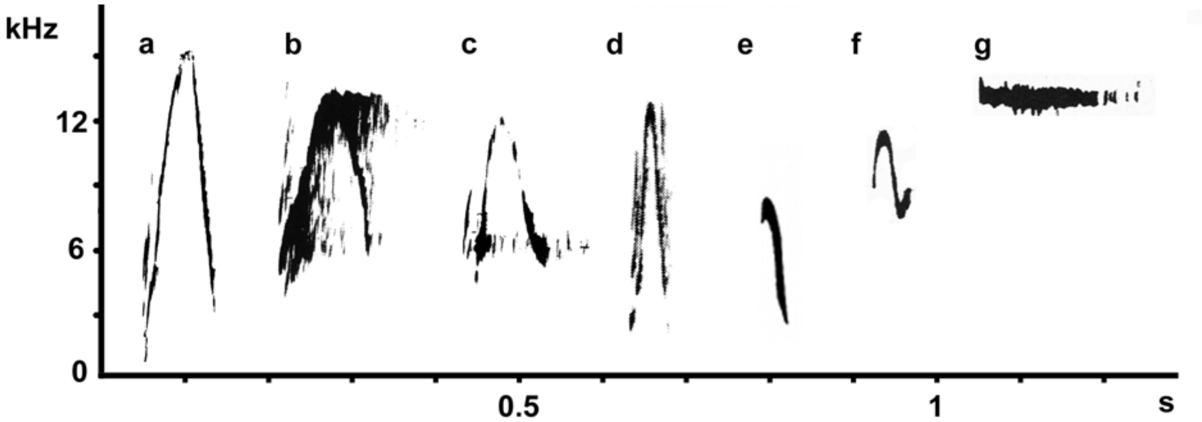

Figure 7. Sonograms of calls of chipmunks (*Tamias*).
A — *T. siskiyou*; B — *T. senex*; C — *T. ochrogenys* (after Gannon & Lawlor, 1989); D — *T. dorsalis* (after Dunford & Davis, 1975); E — *T. striatus* (after Silva *et al*., 1994); F and G — introduced population of *T. sibiricus* in Freiburg (after Geinitz, 1982).

arch-shaped curve, rather than U-shaped curves (Fig. 7A-E). Therefore, there is no reason to suspect that chipmunks introduced to Freiburg originated from North America.

The most reasonable explanation for the observed phenomena is that our data on Siberian chipmunk were collected in taxonomically homogenous part of the range, while specimens introduced to Freiburg were taken from the area which was not included in our investigation. This also would explain why we could not find geographical variation in the structure of calls. Further investigation of chipmunk vocalizations from Japan, Korea and central China should extend our understanding of variation in *T. sibiricus* call structure.

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