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Description of the vocalization of the adult giant mole-rats *(Fukomys mechowi)* and its comparison with vocalization of the other subterranean rodents

Master thesis

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Annotation:

Repertoire of eleven adult giant mole-rats *(Fukomys mechowi)* was described and was compared with repertoires of the other subterranean rodents with different social system and different parameters of underground system.

Prohlašuji, že svou diplomovou práci jsem vypracovala samostatně pouze s použitím pramenů uvedených v seznamu citované literatury.

Prohlašuji, že v souladu s § 47b zákona č. 111/1998 Sb. v platném znění souhlasím se zveřejněním své diplomové práce, a to v nezkrácené podobě – v úpravě vzniklé vypuštěním vyznačených částí archivovaných Přírodovědeckou fakultou - elektronickou cestou ve veřejně přístupné části databáze STAG provozované Jihočeskou univerzitou v Českých Budějovicích na jejích internetových stránkách.

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Radka Bednářová

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Contents

1. Introduction

Vocalization of subterranean animals is depended on physical factors of the tunnels and the anatomical features of their ear. The use of the sight is impossible in dark underground environment, so the voice can be good discriminating aid. It can carry the information of the membership of individuals and their motivational state.

The tunnel, where the sound passes through, represents a specific acoustic environment. Low-frequency sounds around 400 Hz are well transmitted there (Heth et al., 1986; Francescoli, 2000; Lange et al., 2007). Because of their short amplitude these waves are not disturbed by colliding with the walls of the tunnel, contrary to the high frequencies. For easier differentiation of high- and low-frequencies hearing the cut-off between them was set arbitrary by Heffner and Heffner (1993) at the level of 60 dB SPL. The subterranean animals often perceive the sounds at lower values, i.e. about 35 dB by naked mole-rat (Heffner a Heffner, 1993), about 45 dB by coruros (Begall et al., 2004) and about 25 dB by Zambian mole-rat (Brückmann a Burda, 1997).

Recently new information has been uncovered and "stethoscope" phenomenon has been described (Quilliam, 1966; Lange et al., 2007). It means that to the distance of 1 meter there occurs the amplification of the sound at the frequencies 200, 400 and less at 800 Hz.

Despite the similarity of the environment in tunnels, the best sensitivity differs in its frequency in different species. (cf. Heth et al., 1986; Brückmann & Bruda, 1997; Begall et al., 2004; Lacey et al., 2000; Heffner a Heffner, 1991) This can be partly depended on an animal lifestyle. If the animal spends some time aboveground, it must be able to localize sounds in its surrounding, which is possible for high frequency sounds only. On the other hand, the strictly underground animals are freed from this condition and they can perceive only the low frequency sounds which are well propagated in their natural habitat.

Because of the hierarchy which can prevail in social system, the animals need to distinguish between individuals in intraspecific interactions. The harsh contact calls are used for this purpose; they represent the main part of the repertoire of the social species. The solitary animals need to discourage the encounters and decrease the aggression of the mate during courtship. Because of the absence of the social interactions, the contact calls are minimally developed and the group of distress and alert calls is their richest category of the sounds. The richness of repertoire of social species is generally higher than of the solitary (Schleich et al., 2007).

The perception of the sound of underground animals is generally shifted to the low frequencies and several adaptations of the ear develop, i.e. the larger size of auditory bullae and ear-drums, changes of the ratio of the middle ear ossicles (Burda, Bruns and Müller, 1990), the constant width of basilar membrane (Burda, pers comm.; Burda, Bruns and Müller, 1990) and a loss of several auditory muscles (ex Mason, 2004). These specializations also decrease the sensitivity of the hearing apparatus but the attenuation of the sensitivity can be compensate with the several physical parameters of the tunnel (stethoscope phenomenon – see above).

Members of the subterranean genus of *Ctenomys* have larger volume of the auditory bullae than other burrowing *caviomorph Rodents* (Schleich and Vassallo, 2003) The *Chrysochloridae* have hypertrophied malleus (Willi et al., 2006).

On the other hand, the naked mole-rat *(Heterocephalus glaber)* does not reduce or loose any parts of its ear apparatus (Heffner a Heffner, 1993) and the common mole as the member of strictly subterranean *Lipotyphla* has got “normal” proportion of its middle-ear ossicles as well (Nummela, 1995). However, its eardrum is relatively large in comparison with the scull (Aitkin et al., 1982).

The very specific and interesting type of communication of the subterranean animals is vibrational signals which are shifted to very low frequencies – around 100-200 Hz (Heth et al., 1991; Willi et al., 2006). This signal has got two parts, audible and seismic. They differ in their possibilities to propagate for long distances. It generally stands that seismic waves reach onwards.

This type of communication is often used by members of the family of *Bathyergidae*. The signal is usually emitted by members of the solitary species which do not come to the closer contact. It might carry the information about sex and motivational state of the drumming animal and it often serves as a threat against the encounter. The other utilization of vibrational signals in the underground is for orientation and foraging.

The aim of this paper

1. To describe the communication of adult giant mole-rats,
2. To compare their vocalization with other species of subterranean rodents which vary in body size and size of the social system,
3. To look for the differences between species with different parameters of the underground system.

2. Materials and methods

Subjects

The study has been conducted on social giant mole-rat (*Fukomys mechowi*) which belongs to the family of *Bathyergidae.* The experimental animals were born captive and they were kept in the stock at the University of Biological Science in South Bohemia, the Czech Republic.

The single families or pairs were kept in open glass-boxes littered with horticultural peat. The room was artificial lighted in twelve-hour periods. The temperature was kept on the 24±2 ^{o}C. The animals could use several plastic tubes as an imitation of tunnels and flowerpots to simulate the nest. They were fed *ad libitum* on the potatoes, carrots, lettuce, apples and cereals.

Data collecting

The data were collected in March and September 2007 and in March 2008.

The sounds of the eleven animals (five males and six females) were recorded in the conditions of the home glass-boxes. These records served to description of contact and non-aggressive sounds. The experimental aggressive encounters between two males were arranged in experimental open glass-box in a special, separated room. These experiments took 10 to 15 minutes and eight adult males were used in total (five males which were included into non-aggressive recordings and three others).

The records were taken with the undirectional dynamic microphone (MD 735, Sennheiser, frequency range 50 – 18 000 Hz) and recorded with SONY digital audio tape-corder (TCD-D100, frequency response 20 Hz – 20 kHz) on a DAT cassette. The microphone was held in a distance of 15 to 20 cm to ensure that the animals were not disturbed.

Data analysing

Recordings were transferred to the computer and scaled in the programme Avisoft-SAS Lab Pro Software, version 4.39 (2007), where the sampling rate was changed from 44.1 to 22.05 kHz. Following spectrogram parameters were used: Hamming Window, Fast-Fourier-Transformation (FFT) of 256 points and frame size 100%. I measured following variables: frequencies of the beginning and the end of the sound, minimum and maximum frequency, the most intensive frequency, 25%, 50% and 75% quartile, the beginning and the end of the fundamental frequency and the duration of the sound. For scaling sounds of the seismic communication only the frequencies of the beginning and the end of the sound were measured, maximum frequency, the most intensive frequency, duration and intervals between sounds.

Separate analysis was computed in the programme of STATISCTICA StatSoft, Inc. (2004), version 7.0.

The descriptive statistics was used to characterize basic parameters of the sounds. The classification into the categories was testified with the Discriminant Functional Analysis (DFA). For this purpose the logarithmic transformation was taken to normalize the data. The results were visualized in the scatterplots with the aid of factors produced by Principal Component Analysis (PCA).

3. Results

In total, 1 571 sounds of the true vocalization and 351 mechanical sounds have been scaled. According to the behavioural context, the recordings have been classified into four groups: contact calls, mating calls, aggressive calls and mechanical sounds which were recorded in different behavioural context.

Mechanical sounds

Teeth grinding

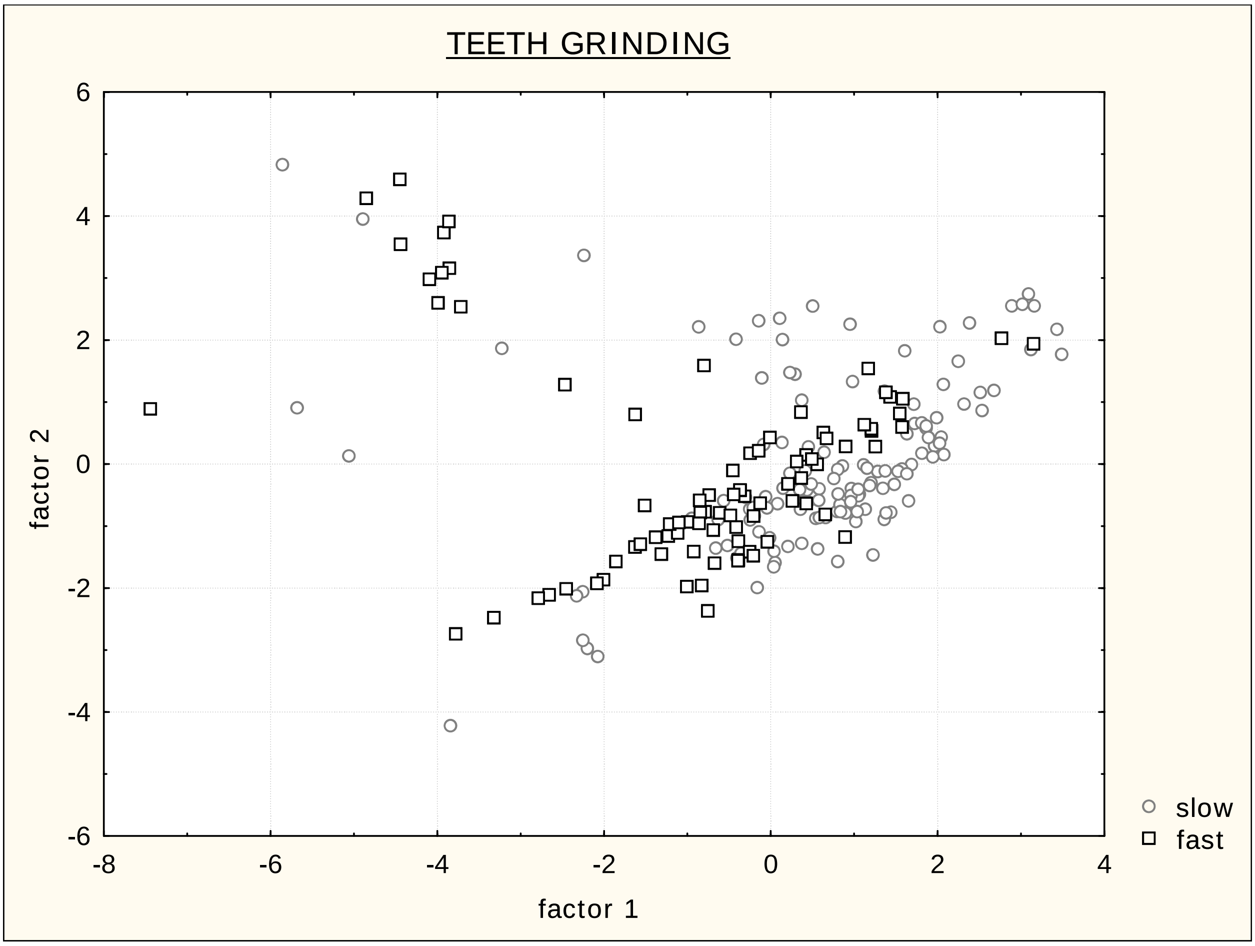


Figure 1.: Plot of two factors gained in PCA showing the separation of the mechanical sounds. (n = 223)

223 sounds were taken in the analysis. Total classification success was 80,00% (Wilks' Lambda = 0,60282) and the sounds were assigned into two categories with following percentage success: teeth grinding slow – 82,83%; teeth grinding fast 72,73%. The basic characteristics of the calls are resumed in the Tab 1.

Table 1.: Summary of basic characteristics of mechanical sounds.

	Count	Main frequency range (kHz) mean ± SD	Minimum frequency (kHz)	Maximum frequency (kHz)	Fundamental frequency (kHz) mean ± SD	Duration of sound (s) mean ± SD
teeth grinding slow	135	3,71±1,97	0,30	21,92	0,64±0,57 0,62±0,54	0,04±0,02
teeth grinding fast	88	4,18±2,23	0,3	21,7	0,9±0,78 0,91±0,83	0,02±0,01

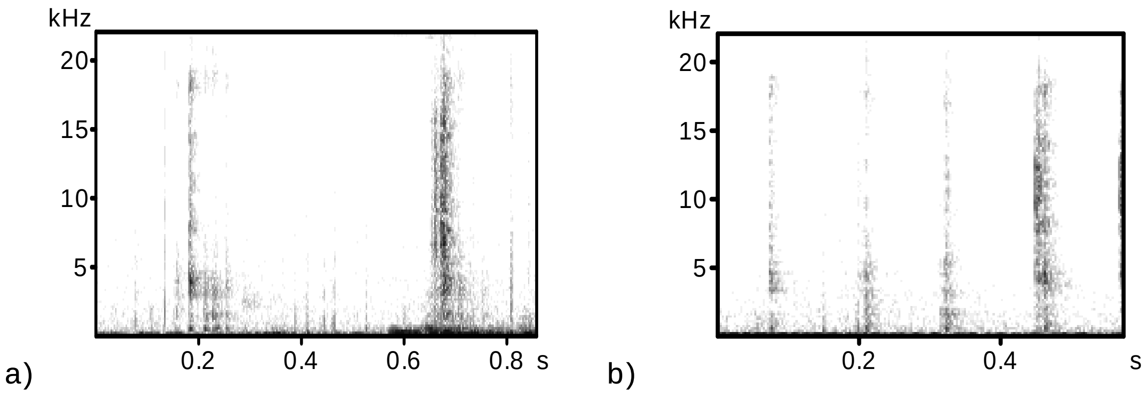


Figure 2.: Spectrographs of the sounds: a) teeth grinding slow b) teeth grinding fast

Teeth grinding is relatively often produced sound. It has two phases (slow and fast) which differs in a movement of the teeth. During the slow phase the upper incisors scrape against the lower incisors and during the fast phase the lower incisors scrape against the upper incisors. The slow phase sounds lower than the fast phase but they both do not differ in the range of frequency – slow phase: 0,3 - 21,92 kHz; fast phase: 0,3 - 21,7 kHz. This sound was mainly produced when the animals relaxed, i.e. in the nest.

Seismic signals

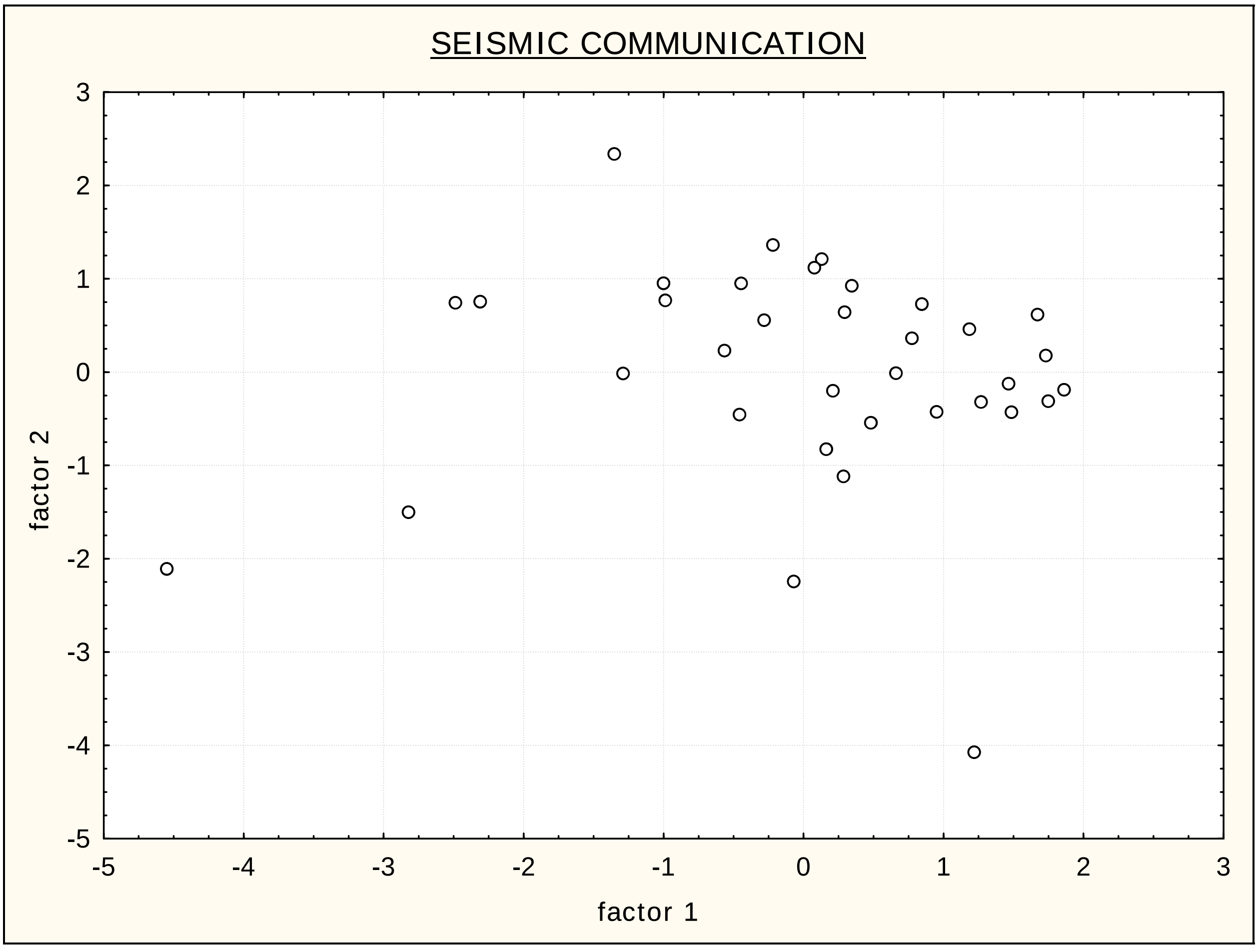


Figure 3.: Plot of two factors gained in PCA showing the separation of the seismic communication (n= 40).

Table 2.: Summary of basic characteristics of seismic sounds

Iterval (s)	Duration (s)	Frequention of begining (kHz) mean ± SD	Frequention of end (kHz) mean ± SD	Maximum frequency(kHz) mean ± SD	Main frequency range (kHz) mean ± SD
0,6±0,21	0,02±0,019	0,47±0,11	0,56±0,14	1,63±0,23	0,45±0,09

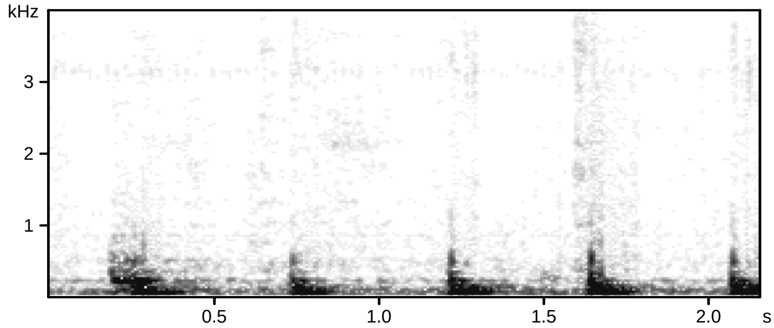


Figure 4.: Spectrograph of the seismic communication

Seismic communication was produced by individuals of both sexes and different age. There were two females beating with their chests against the bottom of the tunnel (represented by the plastic tubes in this case). The recorder was not able to take the whole frequency range which probably interfere into infrasonic part of the sound but the highest frequency of the signal is 1,63 kHz and the most intensive frequency of the audible part moves around 0,45 kHz. This signal is very short, it takes from 0,6 to 2,9 hundredth of seconds and it repeats in second intervals.

The animals implicitly produced this sound in the closed space of the tube but behavioural context of the communication of this species is unclear. The records were mainly taken in two situations: in the aggressive encounters (males) and during feeding (females). Two records were taken in absolutely unknown context.

True vocalization

Contact calls

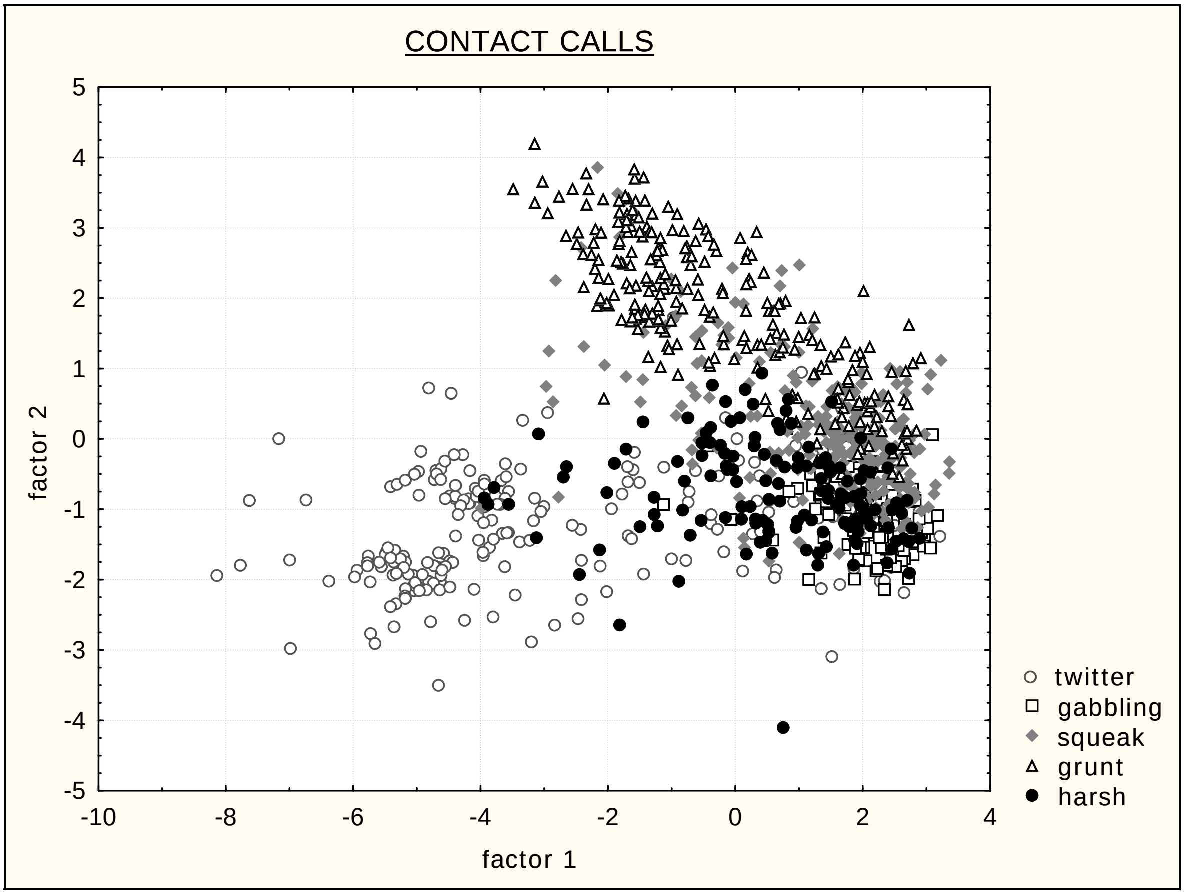


Figure 5.: Plot of two factors gained in PCA showing the separation of the contact calls. (n = 997)

977 sounds were taken in the tests. Totally classification success was 76,36% (Wilks` Lambda = 0,06117) and the single sounds were assigned into five categories with following percentage success: twitter – 82,76%; gabbling – 65,09%; squeak – 75,00%; grunt – 76,95%; harsh – 77,08%. The basic characteristics of the calls are resumed in the Tab. 3.

Table 3.: Summary of the basic characteristics of the contact calls.

	Count	Main frequency range (kHz) mean ± SD	Minimum frequency (kHz)	Maximum frequency (kHz)	Fundamental frequency (kHz) mean ± SD	Duration of sound (s) mean ± SD
twitter	203	3,04±1,19	0,310	9,730	2,57±0,91 2,48±1,02	0,09±0,07
gabbling	106	0,96±0,4	0,3	4,34	0,71±0,23 0,67±0,25	0,16±0,06
squeak	268	1,28±1,08	0,12	10,98	0,69±0,35 0,66±0,35	0,20±0,08
grunt	256	0,25±1,47	0,25	12,1	0,74±0,26 0,72±0,19	0,24±0,06
harsh	144	1,48±1,05	0,25	9,04	1,01±0,66 0,98±0,66	0,06±0,04

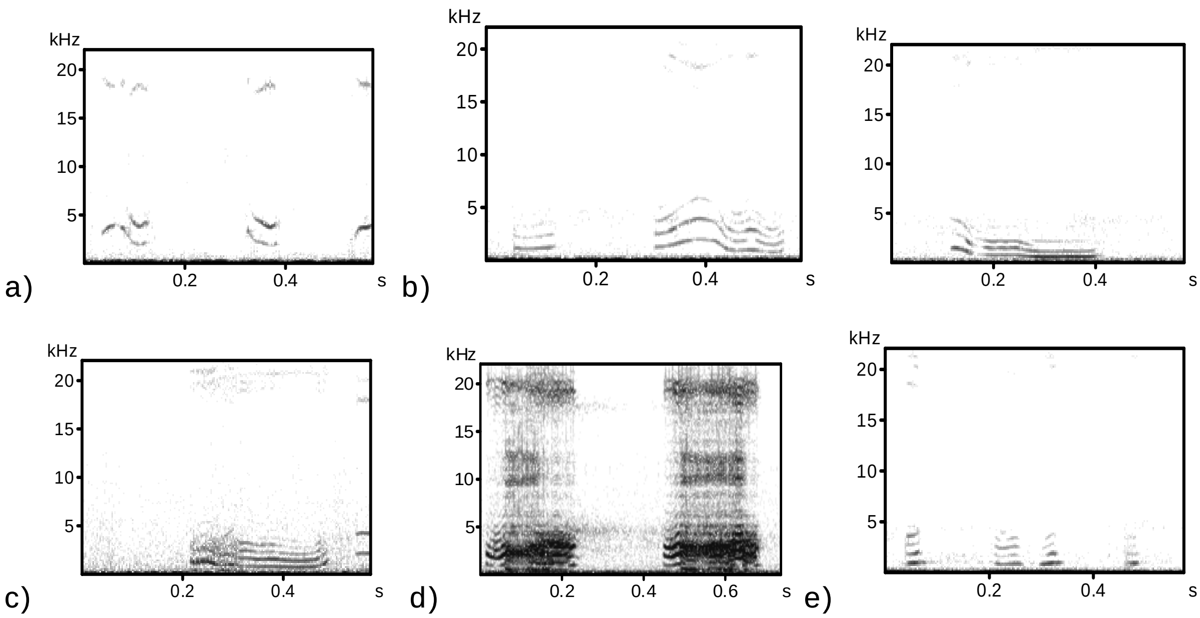


Figure 6.: Spectrografs of the sounds: a) twitter, b) gabbling, c) squeak, d) grunt, e) harsh

These atonal sounds are emitted when the animals come into the non-aggressive contact, i.e. in the nest and after short-time separation. It is difficult to classify these sounds into the separate categories. They usually start as the calm cooing sound on the relatively low frequency and fluently pass into loud, harsh call.

Twitter

Twitter is the only bird-like sound which includes one or few harmonic frequencies which move between 0,31 and 9,31 kHz. The notes take from 0,02 to 0,6 s and they usually indefinitely repeat in the sequences of the syllables. The single notes can appear going directly down or being wavy.

Twitter is emitted by the female lying in the nest, when the other animal comes. If the other animal is a female too, it answers the call. If the other animal is a male, it commonly does not vocalize.

Gabbling

Gabbling is calm, harsh sound which returns to the twitter during welcoming rituals. It is emitted by the incoming female. The single notes interfere from 0,3 to 4,34 kHz and are made up of few harmonic frequencies. The mean of intensities of this sound is placed at 0,96 kHz. It takes approximately 0,16 s and the notes repeat in the indefinite periods.

Squeak

The sound which follows the gabbling is a squeak. This is the mesoscale sound with the frequency between 0,12 – 10,98 kHz. The range of the most intensive frequency is 0,25 – 4,52 kHz with the mean at 1,28 kHz. Squeak takes around 0,2 s but it can continue for 0,49 s.

Grunt

The strongest broadband sound is called grunt. This is the most intensive note among contact calls but this is not the final part of the vocalization. After this sound the vocalization diminishes back to the squeak or to the gabbling.

The frequency range is similar to the squeak (0,25 – 12,1 kHz) but the mean of the most intensive frequency is 2,52 kHz. It takes around 0,23 s but it can run as far as 0,61 s.

Harsh

Harsh is the last category of the contact calls which includes from calm till relatively loud sound characterized by several harmonics and especially very short duration (on the average 0,05 s). Despite this it has got relatively broad frequency range (0,25 – 9,04 kHz) with the most intensive frequency at the level of 1,48 kHz.

Contact calls are produced during welcoming rituals when the incoming animal is provoked to reply to the twitter call. It is often conducted with the special behaviour – nuzzling at the face and browsing on the fur of the incoming animal. Welcoming animal usually intensifies its vocalization but it never reaches the height of the replying animal.

Mating calls

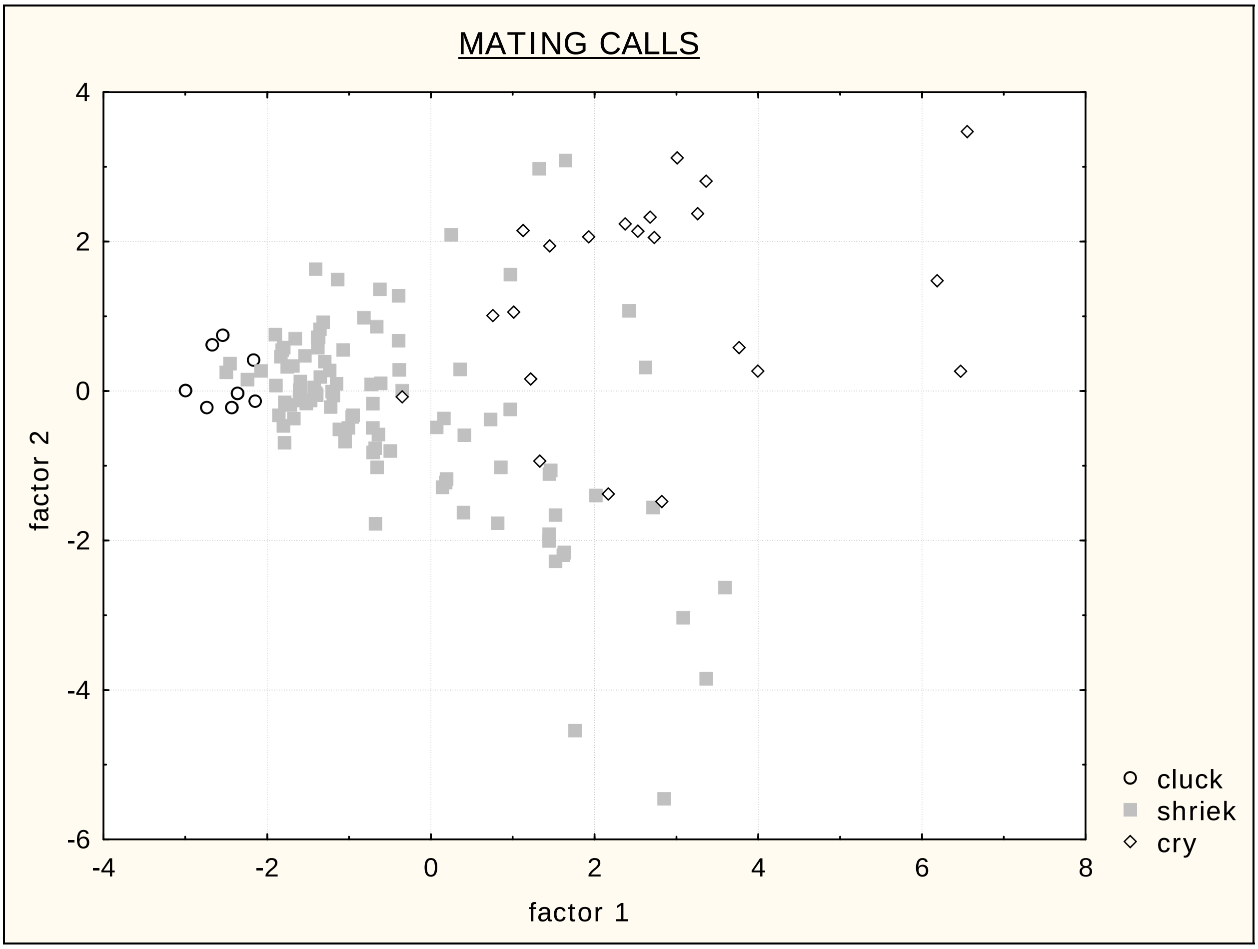


Figure 7.: Plot of two factors gained in PCA showing the separation of the mating calls. (n = 130)

130 sounds were taken in the analysis. Totally classification success was 96,92% (Wilks` Lambda = 0,16302) and the sounds were assigned into two categories with following percentage success: cluck – 87,51%; shriek – 97,00%; cry – 100,00%. The basic characteristics of the calls are resumed in the Tab. 4.

Table 4.: Summary of basic characteristics of mating calls.

	Count	Main frequency range(kHz) mean ± SD	Minimum frequency (kHz)	Maximum frequency (kHz)	Fundamental frequency (kHz) mean ± SD	Duration of sound (s) mean ± SD
Cluck	8	0,43±0,08	0,34	1,37	0,34±0,04 0,37±0,06	0,03±0,01
Shriek	100	0,68±0,25	0,3	8,78	0,47±0,13 0,59±0,28	0,04±0,02
Cry	22	1,16±0,63	0,3	14,21	0,56±0,17 0,55±0,17	0,05±0,03

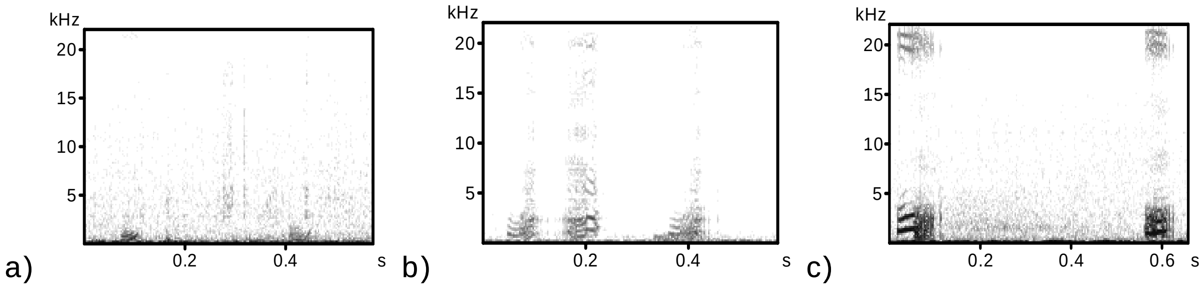


Figure 8.: Spectrographs of the sounds: a) cluck, b) shriek, c) cry

Mating calls are emitted during courtship and copulation.

Cluck

Cluck is a very calm vocalization. It often goes with special behaviour – female runs around the cage followed by male which is taking a sniff at her anogenital and she kicks up her hind legs. This sound is characterized by frequency range of 0,34 – 1,37 kHz and the most intensive frequency range is 0,34 – 0,6 kHz. The duration of this sound does not exceed 5,4 hundredth of second. The single notes are repeated in the irregular indefinite periods.

Shriek

Shriek is intensified cluck-call and it is conducted with the same behaviour. The notes have got relatively broad frequency range (0,3 – 8,78 kHz) and broad duration (0,9 – 13,9 hundredth of second with mean at the level of 4 hundredth of second).

Cry

Cry is the most intensive mating call emitted probably by the female during copulation. This is very regular sound with the frequencies between 0,3 – 14,21 kHz and duration of 5,3 hundredth of second, repeated in approximately half-second intervals.

Distress and aggressive calls

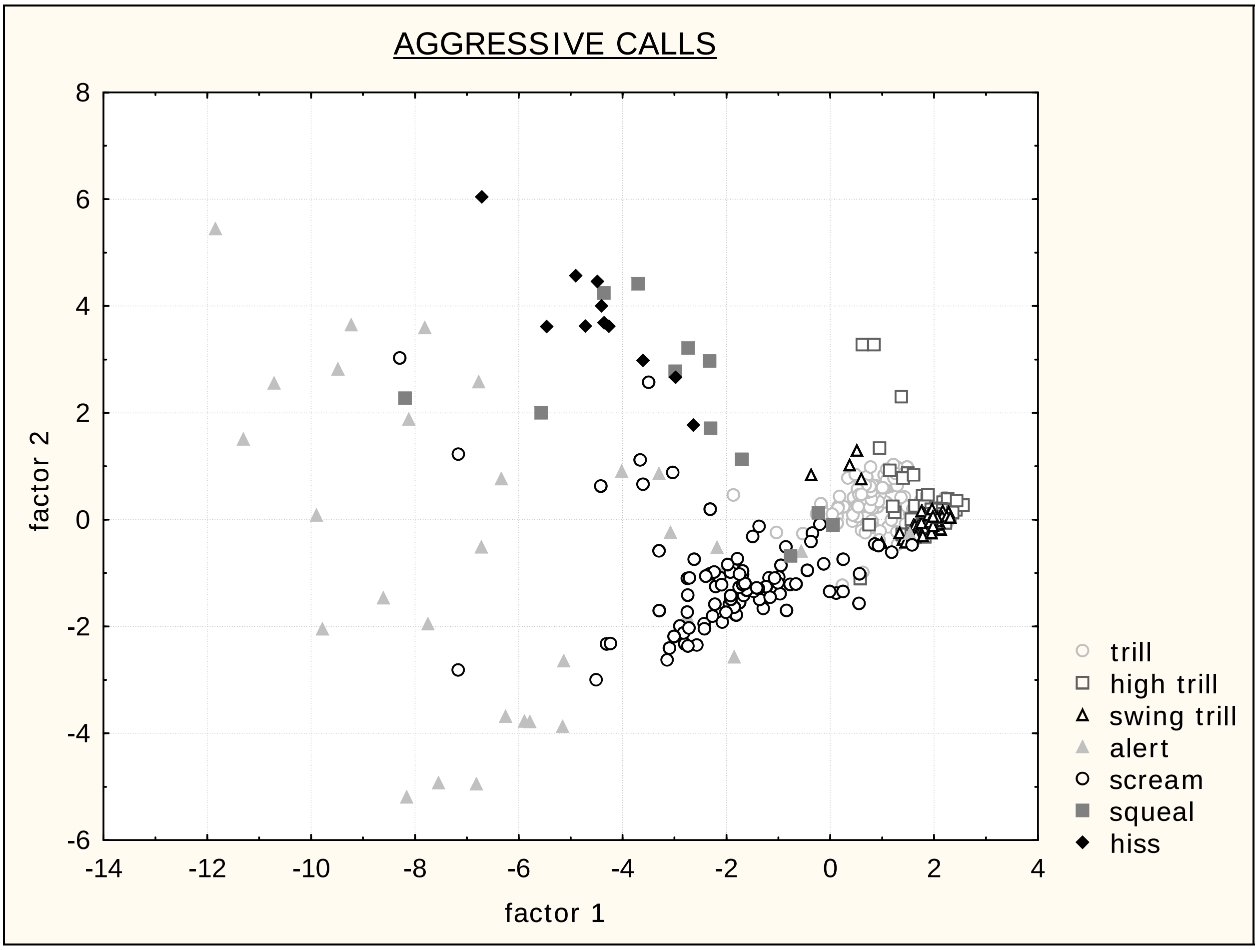
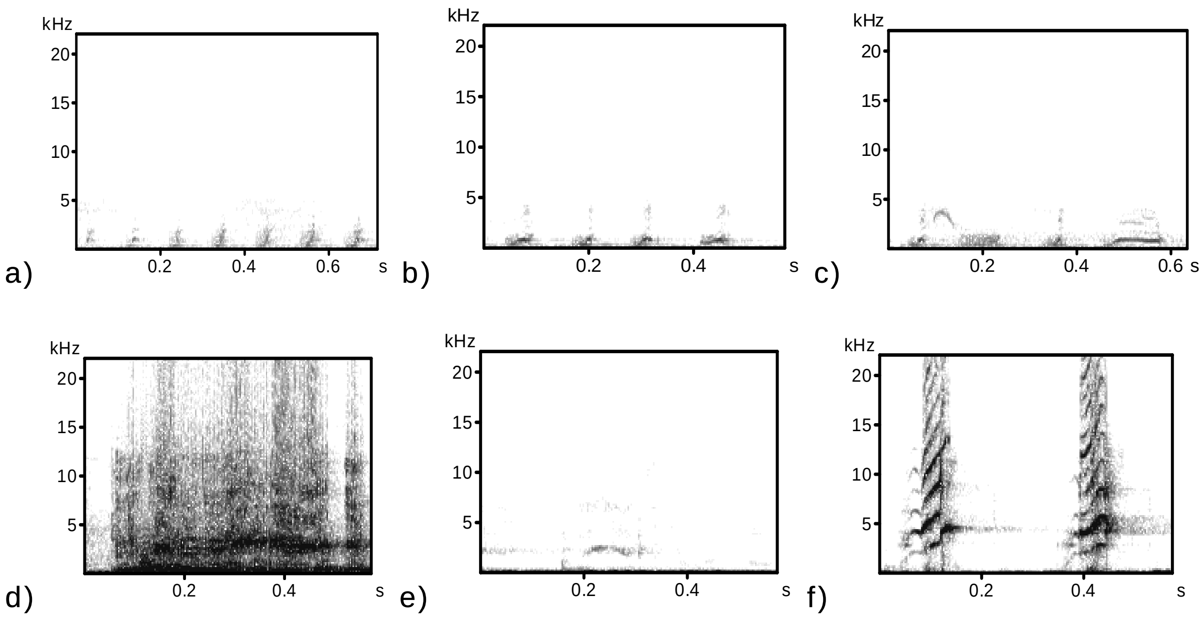


Figure 9.: Plot of two factors gained in PCA showing the separation of the distress and aggressive calls. (n = 522)

522 sounds were taken in the analysis. Totally classification success was 76,63% (Wilks` Lambda = 0,01843) and the sounds were assigned into six categories with following percentage success: trill – 89,76%; high trill – 46,15%; swing trill – 73,53%; scream – 88,54%; squeal – 75,00%; alert – 67,74%, snorting – 80,85%; hiss – 100,00%. The basic characteristics of the calls are resumed in the Tab. 5.

Table 5.: Summary of basic characteristics of distress and aggressive calls.

	Count	Main frequency range (kHz) mean ± SD	Minimum frequency (kHz)	Maximum frequency (kHz)	Fundamental frequency (kHz) mean ± SD	Duration of sound (s) mean ± SD
Trill	166	0,94±0,41	0,38	5,76	0,66±0,16 0,69±0,19	0,03±0,01
high trill	91	0,83±0,49	0,38	12,48	0,50±0,12 0,59±0,41	0,05±0,02
swing trill	68	0,81±0,18	0,34	0,52	0,46±0,05 0,52±0,14	0,07±0,03
Alert	31	4,45±1,54	0,25	22,00	1,52±0,95 1,77±1,29	0,12±0,06
Scream	96	2,23±1,39	0,34	14,42	0,78±0,48 0,83±0,53	0,15±0,07
Squeal	12	2,05±1,81	0,47	12,61	1,82±0,7 1,65±0,93	0,21±0,17
Snorting	47	2,31±1,89	0,25	20,45	1,27±0,93 1,32±1,04	0,1±0,04
Hiss	11	2,58±0,39	0,94	4,39	2,55±0,35 2,49±0,5	0,24±0,07



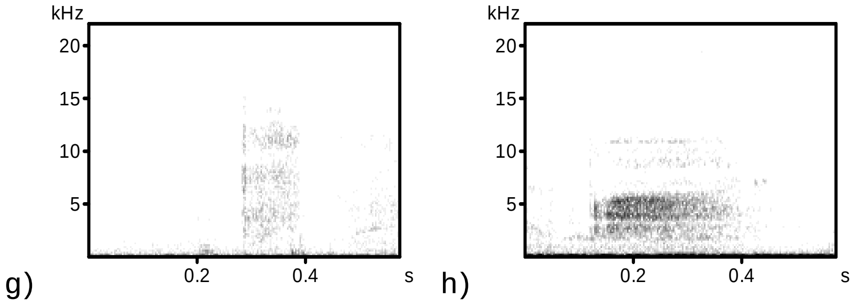


Figure 10.: Spectrographs of the sounds: a) trill, b) high trill, c) swing trill, d) scream, e) squeal f) alert, g) snorting, h) hiss

Trill

Trill is relatively calm vocalization which is produced during interspecific agonistic encounters. Maximum achieved frequency is 5,76 kHz with the most intensive frequency around 0,94 kHz and the duration of 0,025 s. The single notes follow subsequently in 0,048 s intervals and the vocalization takes as long as the threat continues. These sounds are quite uniform, they sound on the one tone and they regularly repeat.

High trill

On the other hand, the high trill, which is similar to the trill, sounds different. It begins on the low tone and goes up to the high frequency. The hole range is from 0,38 to 12,48 kHz. The mean of the intensities is 0,83 kHz. The high trill can be two times longer than trill - the maximum duration is 0,1 s.

This sound is produced during intraspecific encounters with the animal which does not belong to the same family.

Swing trill

Swing trill is a special kind of the trill. It is made up of two nearly separated sounds. They can (but do not have to) be linked up through the treble. Both sounds differ a little with each other but if they are testified together (against the rest of the group), they will result together.

First part of the swing trill sounds as going down to the low frequency, second part sounds as going up to the high frequency. Despite the differences between both sounds, their frequency range is very similar (0,34 – 5,12 kHz of the first part; 0,34 – 5,21 kHz of the second part). The maximum duration differs only slightly (first part: 0,18 s; second part: 0,13 s) and the whole sound takes approximately 0,21 s. Higher differences are apparent only in the median of the most intensive frequency (first part: 0,9 kHz; second part: 0,81 kHz).

This sound follows the high trill in the intraspecific encounters with strange animal and is probably emotionally the most intensive trill.

Scream

Scream is emitted in the most excited phases of the fight which mainly proceeds as the press against the opponent’s incisors. It is really loud call which is conducted with the dominative behaviour. It is characterized with frequency range between 0,38 – 14,42 kHz with the most intensive frequency around 2,23 kHz. The note can be quite short but it can exceed as far as 0,46 s.

Squeal

Squeal is the chirping call which is produced by the subordinated animal during the fight. It seems that this vocalization should still the excited animal because of its emitting during scream of the dominant individual.

Squeal sounds quite calm and the frequency range is placed between 0,47 – 12,61 kHz. The most intensive frequency lies at the level of 2,05 kHz. This sound can last longer than the scream (maximum 0,67 s).

Alert

Alert is relatively short and loud scream. It takes only 0,12 s but it fills up the whole of the frequency spectrum (0,25 – 22,0 kHz). The most intensive frequency moves around 4,45 kHz.

Alert is emitted during the competition for the food and when one animal restricts the movement of the other. This is the most frequently used sound between juveniles but this vocalization is produced by both, adult and juvenile animals of both sexes.

Snorting

Both sexes produce this sound in many different behavioural context, i.e. males produce it during aggressive encounters when an animal is taken off from the colony, as the by-product of comfort behaviour or stilling ritual as well. It is produced by an acute exhalation and we are able to distinguish it easily. Frequency range is placed between 0,25 and 20,45 kHz with the most intensive part between 0,3 – 8,35 kHz. The whole sound takes around 0,1 s.

Hiss

As the snorting, hiss is the mechanical sound produced by intensive breathing. It is emitted during encounters with unfamiliar animal, probably for inspiration of more air and easier identification of the other individual.

The hiss is a quite long sound which takes about 0,2 s but it can continue as long as 0,35 s. It is characterized by the frequency range between 0,94 – 4,39 kHz with the intensity at 2,58 kHz.

4. Discussion

Subterranean animals use several types of tonal and atonal sounds and two types of mechanical sounds. Their rates differ between species. (cf. Schleich, 2007; Begall et al., 2004; Francescoli et al., 2000; Veitl et al., 2000; Brückmann & Burda, 1997; Pepper et al., 1991). The species of *Fukomys mechowi*, which is a social animal with well-developed intraspecific contact calls, use mainly harsh, atonal sounds. They probably include many "individual" sequences and attend determination between individuals (Fitch et al., 2002).

There were described five groups of the contact calls that mainly differ in the frequency range and the intensity of the sounds. The variability within the single groups is quite high. However, more exact classification was hardly possible because of the misting up of the strict borders between single sounds. The hole frequency range reached from 0,3 to 12,1 kHz and the calls were connected into the sequences of indefinite length.

Contact calls represent the most variable and the richest category of the vocalization in social species. They are commonly used during welcoming rituals with the familiar animals but they can be produced in many other non-aggressive encounters. There are described four types of the contact calls with large frequency range in *Spalacopus cyanus* (Veitl et al., 2000) and two types in *Fukomys anselli* (Credner et al., 1997) (the nomenclature after Schleich et al., 2007) . The range of its vocalization did not exceed 12 kHz. This category of the sounds is usually absent in solitary species.

Mating calls of *Fukomys mechowi* were more divided group that included only three sounds. These were connected with the definite phases of the courtship and they were easily recognizable. The intensity and frequency range of the vocalization increased gradually.

Similar situation can be seen in other species of subterranean rodents. The males mainly emit the initiative phase of the vocalization and it can serve to improve the motivational state of the females and to decrease their aggressive propensities, especially in solitary species. The sounds intensify during courtship and culminate during copulation. At that time either only one of the couple can vocalize (Veitl et al., 2000; Credner et al., 1997, Pepper et al., 1991; Schleich & Bush, 2002) or both animals call together (Knotkova et al., 2005; Pepper et al., 1991).

According to the kind of the encounter, the alarm calls are distinguished into two groups – interspecific and intraspecific vocalization. Interspecific vocalization was characterized by trill. This calm, regular sound was emitted pending the continuation of the threat. Other trills were conducted with the intraspecific communication. These two types of the intraspecific trill were produced by the dominant male during the encounter with the member of another family. The intensity and speed of vocalization were given by excitement of the vocalizing animal.

Trill is relatively widespread call in subterranean animals but apparently, only giant mole-rats produce different types of trill in interspecific encounters. The main utilization of this call is during aggressive encounters with conspecific (Veitl et al., 2000; Credner et al., 1997). Pepper et al. (1991) described this vocalization of *Heterocephalus glaber* in two different behavioural contexts, in connection with mating as the „V-trill", and in connection with aggressive behaviour as an „upsweep trill". The tuc-tuc call of *Ctenomys talarum* can be considered as a trill-like sound mainly emitted during fight and other agonistic behaviour. The tuc-tuc sound is explicitly male case (Schleich & Bush, 2002).

The most intensive alarm call is the scream. It is very loud vocalization conducted with the dominative behaviour. Sometimes squeal sounds as an "answer" to this call, which apparently should still the aggression of the dominant animal.

The last alarm call is alert. This short, loud sound should force the relative animal to do what the vocalizing animal wants but this sound is not a provocation to the fight. This vocalization is common to the animals of both sexes and all age groups. The juvenile animals even use this call much more often than the adults do. The alert of juveniles sounds higher but it will probably be characterized by similar frequency range as the adults emit.

This sound is also relatively common. *Spalacopus cyanus* emit the „squeal" during dangerous situations (Veitl et al., 2000), *Fukomys anselli* produce „scream" as an answer to the painful impulse (Credner et al., 1997), *Heterocephalus glaber* produce „grunt" during injuring attack of the familiar animal (Pepper et al., 1991) and juvenile *Ctenomys talarum* produce „grunt" in agonistic encounters (Schleich & Bush, 2002).

Special categories of distress vocalization of *Fukomys mechowi* are snorting and hiss. These are produced mechanically and emitted mainly in aggressive context. This type of vocalization was commonly produced as a by-product of another activity and was not frequent. Recordings of the hiss-like sounds come from many species (Pepper et al., 1991; Credner et al., 1997; Knotková, 2005).

A special group of the communication is mechanical sounds. These are represented by teeth grinding and seismic communication. Teeth grinding is a part of the common vocalization and *Fukomys mechowi* emit it during resting in the nest and during the fight, probably as switch behaviour. This vocalization was recorded in all studied species of the subterranean rodents; sometimes it was produced in a different context than in the case of giant mole-rat. Knotková (2005) refer to distress context of this vocalization of *Heliophobius argenteocinereus*. This sound was not recorded during vocalization of *Spalacopus cyanus* (Veitl et al., 2000).

Seismic communication is the most interesting type of the subterranean animals` communication. There were observed several males of *Fukomys mechowi* to beat with their chests during the agonistic encounters with other strange males. (Two males met together in the system of plastic tubes whereas they were separated with the perforated plastic barrier. Data from these experiments were not taken in the calculation). Several observations of emitting vibrational signals in other behavioural context come from my experiments: females beat with their chests during feeding and one juvenile animal beat due to completely unknown reason. The factors that evoke the production of the vibrational signals of the members of this species remain not exactly decoded.

In general, there are described two types of seismic communication: „headthumping" – with lower jaw against the bottom of the tunnel (*Spalax ehrenbergi* – Heth et al., 1991) and „footdrumming" – with front or hind legs (i.e. *Georychus capensis* – Narins et al., 1997; *Heliophobius* – Knotková, pers. comm.). It might carry much information and it often serves as a threat against the encounter. (For more information see Randall, 2001)

The vibrational signal is well propagated on long distances, so that it has been considered as a long-distance communication medium. The vibrational signals have been supposed as a "privilege" of the solitary species because the social animals meet often together and they do not need to produce long-distance calls.

The other usage of vibrational signals in underground is for a “control” of the neighbour (Randall & Lewis, 1997; Randall, 1997; Heth et al. 1991), for orientation in territory, for foraging (Narins et al., 1997) and for discouraging predator from attack (Randall & Matocq, 1997).

Probably, the most explored genus between rodents is *Dipodomys (Heteromyidae).* The footdrumming of this genus varies between species and within species so much that the animals are able to recognize between individuals (Randall, 1997) whereas the *Eremitalpa granti namibensis (Chrysochloridae)* use the seismic signals in completely distinct way. It perceives the vibration generated by grass in desert by dipping its head into the sand (Narins et al., 1997). In non-communication context insectivorous species of *Talpa europea* use this signal. It probably receives the noise produced during digging and it can “conclude” how advantageous it would be to continue with the work (Quilliam, 1966).

We can also observe the interesting phenomenon in *Spalax ehrenbergi.* The young which live in the mother’s system communicate vocally. During growing up they begin to use vibrational signals and when they burrow their own system and disperse, they begin to use only seismic communication (Rado et al., 1991).

However, the seismic communication is well described only in some species despite many observations of that in different members of the family of *Bathyergidae*. Obtaining of other relevant information about this section of vocalization is required.

The richness of the repertoire and the social system

The social species are supposed to have contact calls as the richest category of the vocalization. The contact calls of the *Fukomys mechowi* (colony size from 3 to more than 20 animals; Scharff et al., 2001) and *Spalacopus cyanus* (colony size around 15 animals; Nowak, 1999) were mainly represented by the sounds of welcoming rituals (present study; Veitl et al., 2000). There was none recording of this type of the call of *Heliophobius argenteocinereus* (Knotková, 2005). On the other hand, this species has the most developed aggressive and distress calls. It is effect of solitary lifestyle of these animals. Eight types of distress and aggressive calls were described in vocalization of *Heterocephalus glaber*. It could be result of the strict division into social castes

(Nowak, 1999) as well as of the size of the group ("as many as 300 individuals" – Heffner and Heffner, 1993). The other social species with well-developed aggressive communication is *Fukomys anselli*. Vocalization of this species (formerly known as "Cryptomys sp.") was described by Credner et al. (1997) and Brückmann & Burda (1997). This "species" was than separate into several distinct species in the genus *Coetomys* (Ingram et al., 2004) and later renamed of the genus *Fukomys* (Kock et al., 2006). So the vocalization described in their papers may be little distorted. The differences in a group of aggressive calls between both species (*H. glaber* and *F. mechowi*) can be result of different sizes of colonies and of the different predation pressure (Credner et al., 1997; Veitl et al., 2000; Schleich et al., 2007). The highest richness of the mating calls of the *Heliophobius* is probably caused by the need of the reduction of the aggression of solitary living females. The results of the comparison of the richness of repertoires of several studied species are resumed in the Tab. 6.

<u>Table 6.</u>: Summary of the richness of the repertoires of true vocalization of several studied species

	Fukomys mechowi[1]	*Ctenomys talarum*[2]	*Spalacopus cyanus*[3]	*Fukomys anselli*[4]*	*Heterocephalus glaber*[5]	*Heliophobius argenteocinereus*[6]
Contact calls	Twitter Gabbling Squeak Grunt Harsh		Cooing Twitter I Twitter II Squeak	Grunt Twitter	Soft chirp Toilet call	
Aggressive (territorial) calls	High trill Swing trill Scream Squeal	Tuc-tuc	Cluck I Cluck II Special vocal	Whistle Trill I Trill II Hiss Grunt I Grunt II	Hiss Grunt Upsweep trill Loud chirp	Low cluck Hissing
Distress calls	Alert	Grunt	Cluck III Squeal	Loud Scream	Scream	Squeaking Scream
Mating calls	Cluck Shriek Cry	Female mating call Male mating call	Creaking Scream	Cluck Shriek Cry	V-trill	Female mating call High cluck Gabbling
Alarm calls	Trill		Trill		Tap Sneeze Low-pitched chirp	
Totally	14	4	12	13	11	7

1. present study; 2. Schleich and Busch, 2002; 3. Veitl et al., 2000; 4. Credner et al., 1997; 5. Pepper et al., 1991; 6. Knotková, 2005
*For comment see text above

The vocal repertoire and underground lifestyle

The underground environment forms special conditions for transmition of the sounds. The best propagated frequencies move around 440 kHz (Heth et al., 1985). These waves are transmitted for relatively short distances but their emission needs only little energy. On the other hand, production of the higher frequencies requires larger amount of energy and the lower frequencies are less transmitted.

One type of mating calls was compared between four species of underground and fossorial rodents. In the Tab. 7 there is summarised comparison of several physical characteristics of the animals, their vocalization and diameter of the tunnels.

Table 7.: Summary of several physical and vocal parameters of the studied species and diameter of the tunnels

Species	Sound	Frequency range(kHz)	Range of the most intensive frequency (kHz)	Body length(cm)	Weight(g)	Diameter of tunnels mean(cm)
Fukomys mechowi	shriek[1]	0,3-8,8[1]	0,3-2,2[1]	100-215[7]	305-481[5]	8[9]
Heterocephalus glaber	low/pitched chirp[2]	1,0-3,0[2]	1,0-3,0[2]	80-92[6]	20-40[6]	3[7]
Heliophobius argenteocinereus	high cluck[3]	0,3-5,8[3]	0,5-4,1[3]	100-200[7]	183-293[5]	6,8[8]
Spalacopus cyanus	cluck[4]	0,6-3,0[4]	1,6-2,5[4]	115-165[7]	60-120[7]	6[7]

1. present study ; 2. Pepper et al., 1991; 3. Knotková, 2005; 4. Veitl et al., 2000; 5. Šumbera et al., 2007a; 6. Heffner and Heffner, 1993; 7. Nowak, 1999; 8. Šumbera et al., 2007b; 9. Lange et al., 2007;

Despite similar conditions of the acoustic environment of the underground, there are slight differences in frequency range between compared species. The frequency ranges are quite different but the most intensive frequencies do not vary so much. The highest frequency (8,8 kHz) was recorded in species of *Fukomys mechowi* (present study). The *Heliophobius argenteocinereus* has got similar body length as *F. mechowi*, though its frequency range is relatively restricted, only 5,8 kHz (Knotková, 2005). It is probably connected with the narrower diameter of the tunnels (8 cm – *F. mechowi* and 6,8 cm – *H. argenteocinereus*) (Lange et al., 2007; Šumbera et al, 2007b). Greater frequency range of the species *F. mechowi* and *H. argenteocinereus* can relate to the greater diameter of their tunnels in comparison with parameters of the tunnels of *S. cyanus* and the *H. glaber.*

The comparison of the range of the most intensive frequency is interesting too. The minimum of that of the species *Fukomys mechowi* and *Heliophobius argenteocinereus* does not exceed the 0,5 kHz. On the other hand, the value of this variable of *Spalacopus cyanus* is placed between 1,6 and 2,5 kHz and the main frequency range does not exceed them so much (0,6 and 3,0 kHz) (Veitl et al., 2000). High rate of the minimum of the most intensive frequency of this species is probably depended on the partly aboveground lifestyle of the animal. The *Heterocephalus glaber* has similar frequency range and ratio of the most intensive frequency. In this case, the high value of the minimum of the most intensive frequency (1,0 kHz) is given by small size of the head.

5. Conclusion

Repertoire of the giant mole-rat *(Fukomys mechowi)* was characterized in this study. The single sounds were classified into four categories according to the behavioural context: contact calls, mating calls, aggressive calls and two types of the mechanical sounds. There was described the seismic communication which is generally attributed to the solitary species.

The frequency range and intensity differ between categories. The lowest frequency was 0,12 kHz (squeak of the contact calls), the highest frequency reached to 22,0 kHz (alert of the distress calls). The mean of the most intensive frequency of the sounds of true vocalization moved around 1,59 ± 0,89 kHz.

6. Citation

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