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New data on the burrowing behaviour of *Microtus* (*Pitymys*) *duodecimcostatus*

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Abstract

Described the burrowing behaviour of *Pitymys duodecimcostatus* in captivity. The digging patterns have been found to be different from those reported in earlier papers. Nine different behaviour patterns were recorded, five of them directly linked to the burrowing activity and the other being unrelated. The burrowing sequence was studied with respect to the five patterns directly related with the burrowing behaviour. Some differences between males and females were shown in the activities more or less related to digging. The main conclusion is that *Pitymys duodecimcostatus* uses the incisors as a digging tool in hard substrata, showing a behaviour similar to that of *Arvicola terrestris*. This behaviour seems to depend on the hardness of the excavated soil.

Introduction

Subterranean mammals have been classified by several authors according to the way they dig into the soil, i.e., their morphological adaptations and their digging behaviour. For instance, Agrawal (1967) distinguishes two kinds of fossorial rodents according to skull and forelegs morphological features, while Dubost (1968a, b) distinguishes three kinds of fossorial mammals: those using only or mainly the forelegs, those using the incisors, and those using teeth and forelegs.

More recently, Gasc et al. (1985) have proposed another classification which deals not only with the digging elements, but also with the burrowing modes. They consider two wide groups according to the parts of the body utilized: those using the forelegs (two subgroups, *Pitymys* and *Eremitalpa*) and those using the teeth (also two subgroups, *Arvicola terrestris* and *Spalax*). According to this classification, *Pitymys duodecimcostatus* would belong to the first group, but there is one difficulty: the Mediterranean vole does not show any modification of the forelegs for digging. This lack of specialization in the forelegs led Casinos et al. (1983) to postulate only a behavioural adaptation in *Pitymys duodecimcostatus,* without morphological changes. We have undertaken a study of the digging behaviour patterns in *Pitymys duodecimcostatus,* an attempt to add new data to those supplied by Casinos et al. (1983).

Material and methods

Observations were made on four adult females and three adult males of *Pitymys duodecimcostatus* caught in the Aisa valley at an altitude of 1680 m, not far from Jaca, in the Spanish Pyrenees. The animals were kept in individual glass boxes. Light followed the normal cycle and temperature was maintained between 10° and 20 °C. Within the boxes there was enough loose soil to allow digging, and also fibrous material for nest building. Food in surplus (mainly peanuts and carrots) was supplied.

Sixteen observations were made for each animal except one, a female, for which there were only thirteen observations possible. Each observation lasted for five minutes, and the different activities and their durations were noted. The observations were done in an experimental enclosure, a glass-walled box of 51 × 72 × 4 cm containing well-packed moist earth (2.3 kg/cm of compressive

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strength). The box was joined by a 10 cm long pipe to another transparent plastic box of 10 × 31 × 16 cm, where the animal transported the earth away from the former box. Later, observations were made in soft, unpacked soil (compressive strength 0.35 kg/cm, i.e., about seven times less than normal soil formerly used) on three adult females and two adult males. The observations were recorded by hand, vocally and videotape.

Nine different behavioural patterns were recorded, five of them directly linked to the burrowing activity, the other being unrelated behaviours. The same patterns were found in both sexes. Behaviour units lasted for different amounts of time, and were recorded as such, not by uniform time units. Sampling method was, therefore, a sequence record with repetitions excluded and with durations of each sequence added (Slater 1978). The behavioural units were the following:

Digging (D): recorded whenever the animal tore out the earth by means of bites. The incisors played the main role, and the forelegs were used mainly to push the loose earth below the abdomen. Both forelegs worked independent by, the body being supported, during the biting phase, by the two hindlegs and by the non-workingforeleg. From time to time, when the amount of earth below the body was high, the animal threw the earth backwards with the hindlegs, in two or three kicks, and during this phase the body was supported on the forelegs. During the biting act (B) the forelegs were used for earth accumulation (A) and throwing away the earth with the hindlegs (H). Burrowing is, thus, a composite three-part behaviour.

Turning (T): recorded when the animal stopped to burrow and turned around by a lateral tumble, going then to the outside box.
Head pushing (Hp): recorded when the animal pushed the earth outwards, from the beginning of the tunnel. The head was used like a bulldozer blade during this activity.

Entrance kicking (Ek): when the animal was in the small plastic box but near the tunnel entrance, and kicked away the earth with the hindlegs before entering again into the burrow.

Tunnel kicking (Tk): the animal entered the tunnel, stopped from time to time, accumulated some earth with his forelegs, and kicked the accumulated earth backwards with the hindlegs. This movement was quite fast, and happened several times between the entrance and the arrival at the digging front.

Grooming (G): this included the common patterns of cleaning the face, the ears and the paws, followed by a regular washing of the body, which finished with the tail. Often it also included scratching the sides with a hindleg, which was also cleaned afterwards.
The other behavioural patterns found are: Feeding (F), Resting (R) and Sniffing (S).

Sequence analysis has been carried out following a first-order Markov model (Fagen and Young 1978). Statistical methods included are the Kolmogorov test for two samples, chi-square test and G test.

Results

Description of burrowing sequence

Burrowing sequence was studied with the first five types of acts, the other having a very low frequency. The sequence was independently established for males and for females, because there were significant differences in the frequency of acts between both sexes on the Markov model (G test level of significance: $p < 0.0001$). The analysis was repeated with only the three burrowing acts (B, A and H) together with the preceding and following acts, with similar results (G test significance level of sex differences: $p < 0.0001$). Sequences were later changed into probabilities (Fig. 1).

Within the burrowing sequence, biting (B) was followed by accumulation (A) with a high probability (0.98 for males, 0.93 for females). Accumulation (A) was then followed by biting (B) more often than by kicking (H) (0.62 for both sexes). After H, the probability of B was also larger than that of other acts, e.g., going outside the tunnel (T = 0.74 for males, 0.61 for females). On average, each burrowing sequence was made up of several repetitions; a low unit was made of three B and two A, while a higher order unit was made of two low-order units separated by one H. The mean number of repetitions for each digging act is shown in Figure 2. Also observations were made on the digging activity of the species in soft, unpacked soil. These show that the animal does not bite (B) at all, but only accumulates (A) and kicks (H) the earth (Fig. 2). There were significant differences between the acts in soft and hard soils (G test level of significance: $p < 0.0001$).

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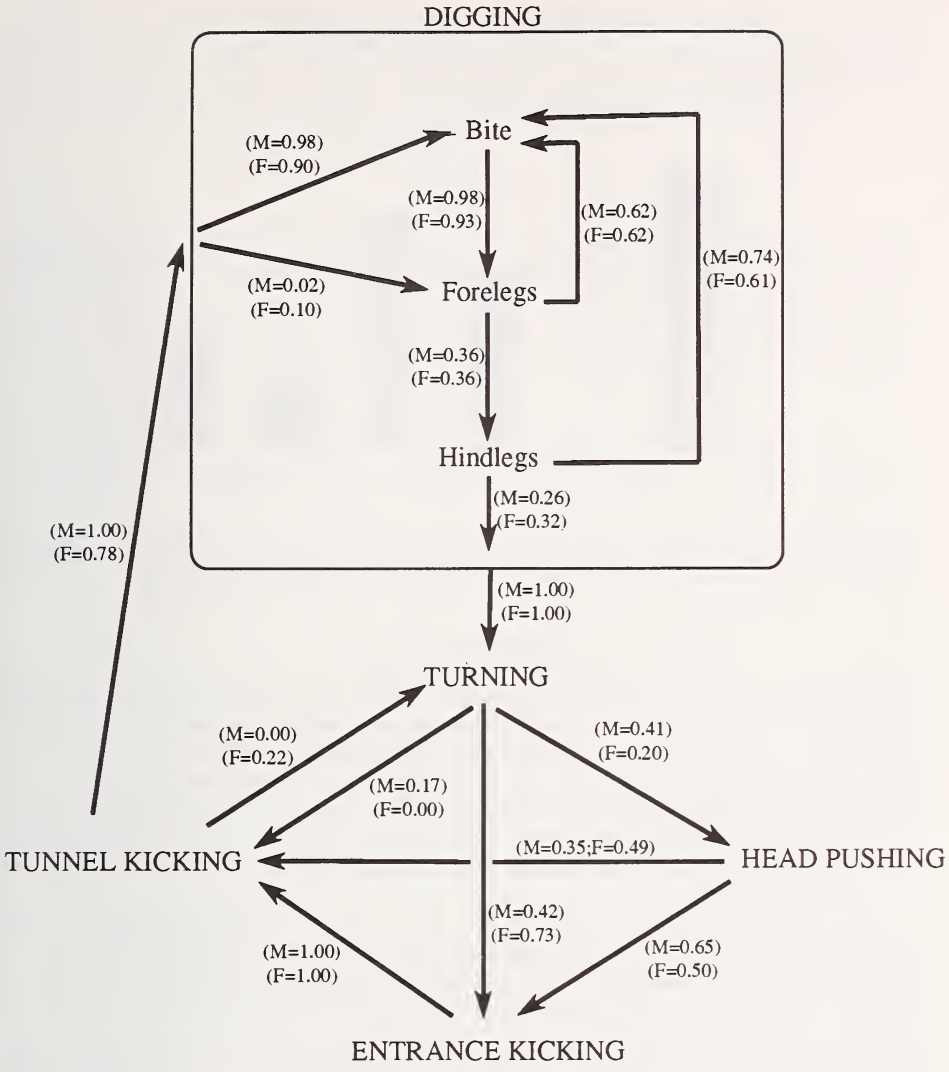

Fig. 1. Burrowing sequence and probabilities of each digging act of *Pitymys duodecimcostatus*. Within the box the set of acts is shown specifically belonging to digging activity. (M = males, F = females)

With respect to the more general sequence, with non digging acts included, the probability of the whole of B being followed by T is 1 in both sexes. T is sometimes followed by Hp, Ek or Tk. In the males, Ek or Hp have a similar probability, while among the females Ek has a higher probability of occurrence. Hp can precede Ek or Tk, with a similar probability in females and a higher probability for the sequence Hp-EK among males. Tk precedes B with a very high probability in both sexes, and within the burrowing sequence, the probability of beginning with biting (B) behaviour is very high, 0.98 for males and 0.90 for females.

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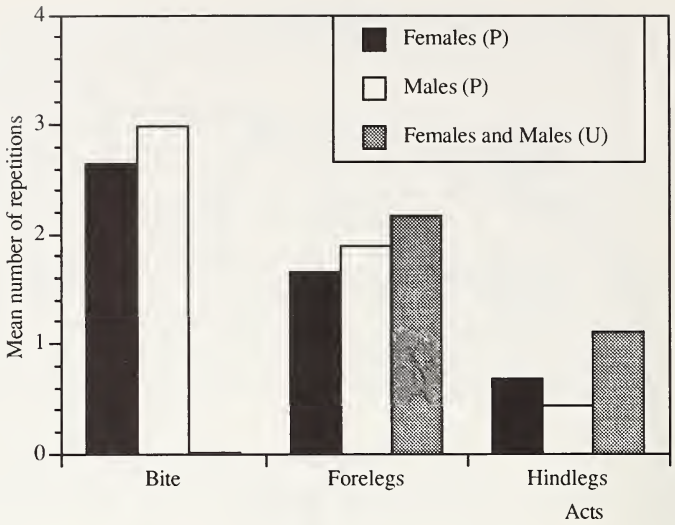

Fig. 2. Mean number of repetitions in each digging sequence, of the acts linked to burrowing behaviour. (P: observation on packed soil; U: observation on unpacked and soft soil)

Duration of sequences

The mean duration of each behaviour in seconds and the corresponding frequence are listed in the Table for both sexes. Some behaviours, such as feeding (F), last for a considerable time, but they are not frequent, and hence their total time is low. Other behaviour, such as digging (D), lasts long and is quite frequent, allowing much time for observation; e.g., total observation time of digging was over 70 min for the males and over 2 hours for females. On the other hand, the shorter behaviour was Ek, with a mean duration of 2.9 seconds in the males and 2.5 seconds in the females. The remaining acts were of intermediate duration.

There is some difference between males and females in the mean duration of each behaviour. When these differences are significant this is indicated in Table 1. The table also shows the percentage of time spent by each sex on each type of behaviour. A significant difference of the total time spent for each behaviour has also been shown (G test level of

Mean duration of each act in seconds for both sexes and percentage of total time spent in each kind of burrowing behaviour for both sexes

Acts	Mean duration				Percentage of time	
	male	(n)	female	(n)	male	female
Digging	16.0	(265)	14.1	(562)	33	41
Turning	7.1	(377)	3.9	(574)**	20	13
Head pushing	6.5	(136)	4.1	(98)	7	2
Ent. kicking	2.9	(262)	2.5	(521)	6	7
Tun. kicking	7.0	(394)	7.2	(656)	21	26
Grooming	8.6	(68)	7.6	(107)	4	4
Feeding	13.0	(9)	16.5	(13)	1	1
Resting	8.4	(54)	2.7	(71)*	3	1
Sniffing	6.0	(84)	3.5	(161)	4	3

* p = 0.01, ** p = 0.003 (Kolmogorov-Smirnov test).

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significance: $p < 0.001$). Both males and females spent the main part of their time with digging (D = 43 % females and 32.7 % males), followed by the time spent on driving the earth out of the tunnel (Tk = 26.5 % females and 21.2 % males). The behaviours with the greatest difference between sexes were resting (R), and turning in the tunnel (T).

Discussion

With reference to the description and Figure 1 (which depicts this sequence) we can see that *Microtus* (*Pitymys*) *duodecimcostatus* uses mainly the mouth for burrowing, the forelegs to accumulate soil and the hindlegs to kick the earth away. This agrees with the conclusions of Agrawal (1967) for *Pitymys sikimensis,* but does not agree with the conclusions of Casinos et al. (1983). According to these authors, *P. duodecimcostatus* uses its legs for burrowing, and Gasc et al. (1985) included this species within the group of hand-diggers, and even names this group as *'Pitymys system'*.

It is possible thus to understand the lack of morphological adaptations for digging at the forelegs of this vole, because it uses the teeth, not the front feet, as does *Pitymys sikimensis*. Agrawal (1967) stated that the latter species uses its incisors to burrow and that skull and teeth morphology seem to be highly modified to fossorial activity. Moreover, Mathias (1990) found a strong proodontism both in *P. lusitanicus* and in *P. duodecimcostatus,* which is taken to be an adaptation to fossorial life.

Thus, the only remaining problem is the misconception by Casinos et al. (1983) as to the burrowing method of the Mediterranean vole. The observations made by Casinos et al. (1983) and by Gasc et al. (1985) appear to be quite reliable. Therefore, the best way of explaining the discrepancy between their and our results is to suppose differences in the procedures of observation. The most evident of these is the soil supplied to the animals: the soil we used was well-packed, moist earth, while that of the former authors was loose peat; due to the need of using a substratum transparent to X rays required for radiocinematography. The burrowing behaviour of *P. duodecimcostatus* changes with the consistency of the available substratum. Thus, in our observations the normal sequence was: -B-B-B-A-A-H-B-B-B-A-A-H-B-B-B-, but in different substrata the number of repetitions of each act and the general pattern could be modified, with the number of bites larger in hard soils and lower or null in soft soils.

The main conclusion is that *Pitymys duodecimcostatus* uses the incisors as a digging tool in hard substrates, showing a behaviour similar to that of *Arvicola terrestris,* according to the observations of Airoldi et al. (1976) and Laville (1989). In this case the species should be included in the group called "bite and tear system of *Arvicola terrestris*" by Gasc et al. (1985).

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Zusammenfassung

Neue Angaben über das Verhalten von Microtus (Pitymys) duodecimcostatus beim Graben

Bei in Gefangenschaft gehaltenen Tieren von *Pitymys duodecimcostatus* wurde das Verhalten beim Graben untersucht. Die dabei aufgezeigten Verhaltensmuster unterscheiden sich von denen in früher veröffentlichten Arbeiten. 9 verschiedene Verhaltensmuster wurden untersucht, von denen 5 mit der

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Grabaktivität in direktem Zusammenhang stehen. Die übrigen sind unabhängig davon. Die Abfolge der Grabvorgänge wurde anhand dieser 5 Verhaltensmuster untersucht. Das beim Graben gezeigte Verhalten zeigte einige Unterschiede zwischen den Geschlechtern auf und scheint von der Festigkeit der ausgegrabenen Erde abzuhängen. Die Ergebnisse zeigen, daß *Pitymys duodecimcostatus* bei hartem Substrat die Schneidezähne benutzt und damit ein ähnliches Verhalten wie *Arvicola terrestris* aufweist.

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