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Endoscopic observations on tunnel blocking behaviour in the European ground squirrel (*Spermophilus citellus*)

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The use of endoscopic equipment in field studies enables researchers to observe the behaviour of ground-dwelling animals inside their burrows. The burrows of the European ground squirrel (*Spermophilus citellus*) are suitable for studying subterranean behaviour by use of this method, both because of the tunnel size (approximately 5–10 cm in diameter) and their visibility in the field. Each adult ground squirrel occupies one burrow system, which is relatively simple. Typically, the number of entrances varies between one and five, while the length of each tunnel measures between 0.7 and 4.5 m, at a maximal depth of 2 m. The nest chamber can be found at a depth of about 0.5 to 1 m (Ružić 1978).

We investigated burrows of the European ground squirrel in the Kiskunság Nemzeti Park at Bugac Puszta, Hungary (46°38′ N; 19°40′ E). The burrows were inspected from 21. 07. to 08. 08. 1997, using a 205 cm long, manoeuvrable fibre optic industrial endoscope (Olympus), attached to a video system. In total, we investigated 87 entrances of ground squirrel burrows in an area of approximately 3.5 ha.

In 71 cases (82%) a tunnel block was detected at an average distance of 57 cm (sd 30 cm; range: 20–170 cm) from the entrance. In the remaining 16 cases, a) there was either a dead end to the tunnel (9 cases), b) the endoscope got stuck (4 cases), c) the endoscope was too short (1 case), d) or a U-shaped tunnel caused the endoscope to emerge from another entrance (2 cases). In four cases we were able to push the endoscope through the tunnel block. This enabled us to measure the length of these tunnel blocks, which were 30, 30, 40, and 40 cm, respectively (to the nearest 5 cm). There was a clear distinction between dead-ending tunnels and tunnel blocks. A dead-ending tunnel was found to have a smooth cup at the end and always a heap of sand outside the entrance. Blocked tunnels, however, were always filled with loose sand, sometimes with some plant material. 52 of these blocked tunnels (73%) had no sand heap outside, therefore they must have been dug from the inside (Ružić 1978). In three cases a ground squirrel was actually observed while blocking its tunnel. These ground squirrels used mainly the front legs for digging through the sand block, while upward movements with the head were used to close the tunnel block from the inside. The final result was indistinguishable from tunnel blocks observed otherwise. An impression of a tunnel block in a ground squirrel burrow is presented in figure 1.

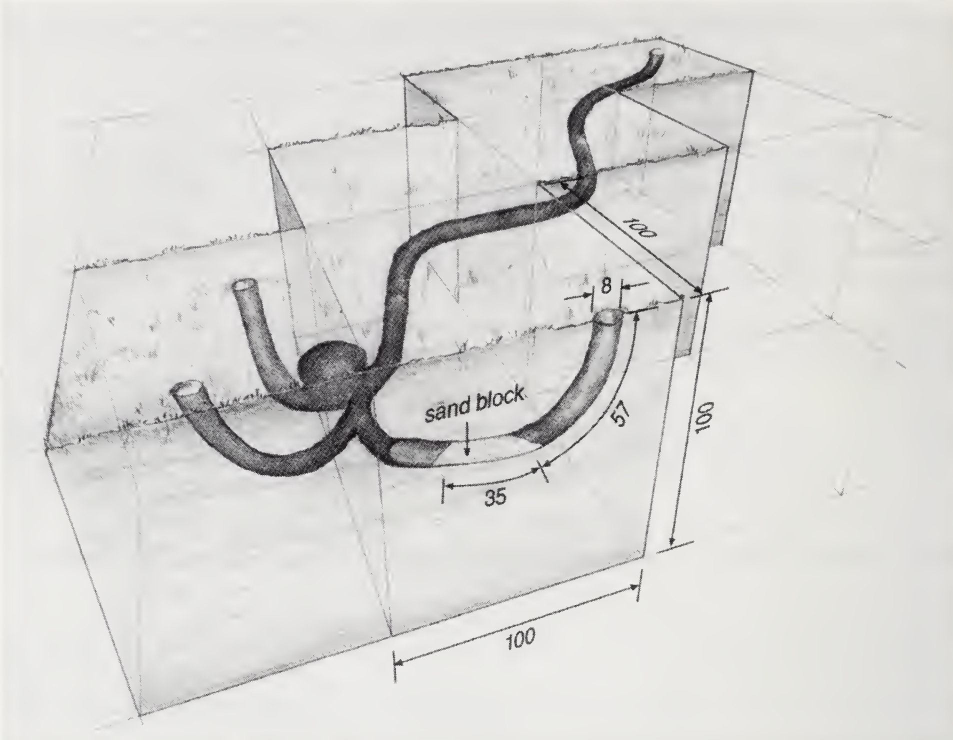

Fig. 1. Impression of a tunnel block in a ground squirrel burrow, excavated near the study area. Measures (in cm) are averages as mentioned in the text. The nest chamber was located at 50 cm below the surface, the deepest point of the burrow at 90 cm below the surface.

It is unlikely that insertion of the endoscope caused the ground squirrels to block their tunnels for two reasons. Firstly, 22 of the burrows were inspected at least 1 hour after the end of the activity phase of the ground squirrels which was measured to be approximately at 18:00 h MET in late July. Of these cases, 21 (95%) were found to be blocked. The one which was not, contained remainders of a tunnel block at 56 cm, and a dead juvenile ground squirrel at 110 cm from the entrance. Secondly, in six other cases we inserted the endoscope in a burrow from which a ground squirrel had just been caught by trapping at the burrow entrance. Here, we also found tunnel blocks at an average distance of 50 cm from the entrance. This suggests that the ground squirrels also block their tunnels while leaving their burrows, even when there is no direct disturbance due to the endoscope or due to people at the site of the burrow. After releasing these animals in their burrows, their behaviour was observed with the endoscope already placed in the tunnel. In all cases the ground squirrels dug their way through the tunnel block within a few seconds, closing it behind them as described above.

We suggest that free-ranging European ground squirrels are actively avoiding predation by blocking their burrow tunnels with sand, a behaviour that was also found in wood mice in the laboratory (KHIDAS and HANSELL 1995). They do so both when entering and leaving their burrows. We suppose that ground squirrel predators in the area, such as the large whip snake (*Coluber jugularis*), the weasel (*Mustela nivalis*), the common polecat (*Mustela putorius*), and the step polecat (*Mustela eversmanni*) will be less successful in hunting ground squirrels from their burrows when the tunnels are blocked. Furthermore, blocking a tunnel at 57 cm distance from the entrance may have the advantage that the block distant from the entrance still leaves the ground squirrel with a quick refuge against (aerial-) predators while being at the surface.

An important consequence of this behaviour might be that the ground squirrels exclude themselves largely from any outside information, such as time of day or weather conditions while being inside a blocked burrow. Another consequence is the loss of mass air flow, which should have an important effect on the concentration of respiratory gases (Wilson and Kilgore 1978; Withers 1978). Low O_2 and high CO_2 concentrations have indeed been measured in ground squirrel burrows during the active season (McArthur and Milsom 1991 a; Maclean 1981; Baudinette 1974). From this, one would also expect ground squirrels to have a high tolerance to hypoxia and hypercapnia, which was shown in the Columbian and golden-mantled ground squirrel (McArthur and Milsom 1991 b). To our knowledge, however, tunnel blocking behaviour has not previously been described in ground squirrels.

It is important to distinguish between hibernation-associated entrance blocking (Ružić 1978), and tunnel blocking during the active season. Firstly, the period in which this study was performed was before the onset of the hibernation season in the European ground squirrel. This is illustrated by the fact that during the study period we caught several adult females, which are the first to start hibernation in the European ground squirrel (Millesi et al. 1998). Secondly, hibernation-associated blocking occurs at the entrance, and not at an average distance of 57 cm from the entrance, where we found the tunnel blocks during the active season.

To our knowledge, this is the first field study describing tunnel blocking behaviour in a ground-dwelling mammal. The description of this behaviour may have important implications for interpreting studies on activity patterns, respiration physiology, and predation in ground-dwelling mammals.

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