

## Scent marking by red foxes in Central Poland during the winter season

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Using a method of snow-tracking the characteristic of objects marked by foxes *Vulpes vulpes* Linnaeus, 1758, was determined. It was found that foxes often marked undurable objects: low plants, fallen sticks and twigs, sites of hunting for prey, carrion, and flat surfaces of snow. Marks placed on such objects predominated among all marks. Males more actively than females deposited their urine marks on more permanent objects (trunks, stumps, stones, burrows, knolls etc.) whereas females more frequently marked flat surface of snow. Mean frequency of scent marking was estimated as 4.41 urine marks and 0.35 seats per 1 km of fox trail. Decrease in intensity of defaecation as an effect of decrease in food consumption in certain periods e.g. at rut, was observed. The increase in urine marking activity in the second half of winter, mostly in the forest area, may be interpreted as a defence of vicinity of the future den. Spatial pattern of marking in fox territories was positively correlated with rodent density. Foxes marked border and inner parts of their territories with similar intensity.

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### Introduction

The role of scent marking in mammals for communication between individuals and interspecies relations has been the subject of many studies. In particular, the scent marking behaviour of foxes (*Vulpes vulpes* Linnaeus, 1758) has been widely analysed (Korytin 1968, Henry 1977, Macdonald *et al.* 1979) the results of observations and experiments often being contradictory.

In this paper scent marking behaviour of foxes was studied by snow-tracking during several winter seasons. The aim of this paper is to identify objects marked by foxes, to estimate intensity and variability of urine and seat marking and to assess spatial distribution of marks within the fox territory.

### Study area and methods

Investigations were carried out in Central Poland in the vicinity of Rogów (51°48' N, 10°53' E). The study area of 21 km<sup>2</sup> was a mosaic of forests and fields. Farmland was dissected by a dense network of roads and balks dividing small fields (most of them less than 1 ha in the area). Four fox families inhabited this area and the average winter density of the predators was estimated as 0.71 individuals per 1 km<sup>2</sup> (Goszczyński 1989 a, b). Density of rodents changed from several individuals per 1 ha to a maximum of 80 individuals per 1 ha (Goszczyński 1985).

The major set of data used in this paper was collected in 1984 — 1988. Some observations made in previous years were also included into the analysis. Period of winter tracking of foxes depended on snowfall and duration of snow cover, but usually the predators were tracked from November to March. To simplify collection of data, the trail of traced animals were divided into sections of 250 meters. Each section was drawn on the map of the study area. For each section the following data were recorded: freshness of trail, cases of finding carrion or other food remains, hunting or attempts of hunting, cases of marking by urine or scat, number of other fox and rodent trails crossing the observed section. This last information was used for computing an index of intensity of area searching by foxes and rodents ( $A$ ). This index ( $A$ ) represents the number of fox and rodent trails per 1 km of the fox trail per 24 hrs. Simultaneously, in the same study area the studies on spatial distribution of foxes were conducted (Goszczyński 1989b). It was found that the size and spatial distribution of family territories during 4 consecutive winters were stable. These findings justified pooling 4 years' data on scent marking activity. They also allowed for an estimation of the distribution of marks in different parts of previously delimited fox territories. For this purpose the whole study area was divided into  $400 \times 400$  m squares. All sections of trails located within a given square were used to calculate: (1) Intensity of trail marking ( $ITM$ —number of scats or urine marks per 1 km of trail); (2) Intensity of home range marking ( $IHRM$ —number of scats or urine marks per 1 ha per 24 hrs). The modified formula of Priklonski (1965) was used for  $IHRM$  computation:

$$IHRM = (ITM \times A \times 1.57) : 100$$

The product  $A \times 1.57$  characterized length of fox trail within an area of 1 ha. If a section crossed two squares then the value corresponding to this section was attributed to both squares. These squares in which number of the trail sections was below 10 were omitted from the analysis.

A total length of trail used for estimation of intensity of defecation was 691 km (fields 297 km, forests 394 km). The distance used for estimation of urine marking activity of foxes was somewhat shorter, and equal to 561 km (fields 240 km, forests 321 km). Some sections of trails in which the frequency of urine marking could be underestimated due to the weather conditions (too intense insolation or snow-thaw) were also omitted. This concerns mostly data from tracking conducted in a field area in March. In 2141 cases (1940 urine marks and 203 faeces) the detailed information concerning places of mark deposition was collected. On the basis of these informations the classification of marked objects was made.

## Results

### Characteristics of marked objects and sites

In the forest, foxes most frequently deposited urine marks on trunks and stumps of trees, on bushes, fallen twigs and sticks and also on flat surface of the snow. In fields, most of fox urine marks were recorded on cultivated plants and on weeds, on balks, and also on tops of clods. Faeces were most often deposited on flat surfaces of snow, in killing sites and on carrion or near carrion (Table 1).

A total of 240 cases of digging in snow or in snow and litter, in search for rodents were recorded. The foxes made attempts to capture rodents with mean frequency 3 times per 1 km of their trails. Only in 26 cases was it possible to determine on the basis of small pieces of fur or blood-drops, that the hunting was successful. In both, successful hunting ( $n = 26$ ) and hunting of unknown results ( $n = 214$ ), the frequency of urination on digging sites was similar (3 and 29 times respectively). The digging places were rarely (3 times) marked by scat deposition. Quite often small insectivore mammals captured by foxes were found on the trail. These were 12 shrews *Sorex araneus*, 1 mole *Talpa europaea* and 1 water shrew *Neomys fodiens*. Only 3 of them were

Table 1. Objects and sites marked by foxes, and frequency of their marking.

Objects	Forest areas				Field areas			
	Urine		Seat		Urine		Seat	
	n	%	n	%	n	%	n	%
1. Tree trunks and stumps	331	26.1	5	4.1	14	2.1	-	-
2. Shrubs	228	18.0	1	0.8	27	4.0	1	1.2
3. Herb-layer	172	13.6	1	0.8	-	-	-	-
4. Cultivated plants and weeds	-	-	-	-	177	26.4	1	1.2
5. Carrion, prey, sites of killing	34	2.7	20	16.4	33	4.9	7	8.6
6. Fox burrows	20	1.5	2	1.6	-	-	-	-
7. Stones snugs, posts, piles of wood, knolls, roads	65	5.1	8	6.6	69	10.3	4	5.0
8. Snowhills and snowdrifts	34	2.7	8	6.6	9	1.3	4	5.0
9. Balks and tops of clods on fields	-	-	-	-	215	32.0	-	-
10. Sticks, twigs and dead leaves, litter in forest	193	15.2	-	-	40	6.0	-	-
11. Flat surfaces of snow	181	14.3	75	61.5	74	11.0	63	77.8
12. Animal trails and scats	9	0.7	2	1.6	10	1.5	11	11.2
13. Other objects	2	0.1	-	-	3	0.5	-	-
Total number of marks	1269	100.0	122	100.0	671	100.0	81	100.0

partially eaten. One of these insectivores was urine marked. Larger prey and carrion found by foxes (dead roe deer, hares, dogs and other domestic animals) were more often marked. Among 105 recorded cases of larger prey and carrion found on the fox trails, 34 were marked by urine and 24 by scat. It was observed that near the carrion of roe deer and dogs successively eaten by foxes, the number of seats accumulated. In some cases the faeces were deposited directly on the carrion. Some times carrion (mainly hens and bones of domestic animals) was only visited by foxes, without attempts of eating or marking.

Both, in the fields and in the forest, the foxes most often marked undurable and inconspicuous objects, which could carry the olfactory information only for a short

Table 2. Number of marks deposited by foxes on objects of different durability (urine and faeces together). Permanent objects: positions 1, 6, 7, 9, and partly 5 and 8 of Table 1. Undurable objects: positions 2, 3, 4, 10, 11, 12, and partly 5 and 8. Intermediate objects: position 2 and some objects from position 13 of Table 1. No data for fields in 1988/89.

Category of objects	Winters						Total	Per cent
	84/85	85/86	86/87	87/88	88/89	Previous winters		
	Forest							
Permanent	100	65	179	90	11	29	474	34.1
Undurable	130	112	217	111	31	54	655	47.1
Intermediate	81	45	93	16	7	20	262	18.8
Total	311	222	489	217	49	103	1391	100.0
	Fields							
Permanent	140	67	9	69	-	27	312	41.5
Undurable	118	124	52	89	-	27	410	54.5
Intermediate	18	4	3	1	-	4	30	4.0
Total	276	195	64	159	-	58	752	100.0



time. This group of objects included flat surfaces of snow, grasses, undergrowth, weeds, and places in which a fox hunted for rodents. This kind of marking rapidly disappears after change of weather conditions *e.g.* thaw, snowfall. The predominance of marking on such objects and places was observed in all studied years. Urine marks placed on such objects made up to fifty percent of all recorded cases (Table 2). On the other hand, more permanent objects like tree trunks, stumps, piles of woods, tops of clods and so on, were used for marking in 34–42% of cases. For methodical reason the category of intermediate objects was distinguished. These were shrubs and samplings, difficult to classify unequivocally. They accounted for 19% of marking found in the forest and about 4% found in fields (Table 2).

In the case of urine marking it was established that 70–80% of all marks were made on plants, stones, barks and similar objects which raised above the ground (Table 1). Approximately 10–15% (on average 13%) of urine marks foxes were placed directly on flat surfaces of snow, whereas faeces were placed there in 60% of cases. The comparison of these percentages revealed that faeces were significantly more often placed on flat surfaces than urine marks ( $d = 28.6, p < 0.001$ , test for comparison of two percentages).

#### Intensity of scent marking and its changes during winter season

Taking into consideration all data, it was found that an average frequency of marking in winter was 0.35 of scats and 4.41 urine marks per 1 km of fox trail. A significant decrease in frequency of marking by faeces deposition was observed in the first 10-day period of February and at the beginning of winter in November/December (Fig. 1).

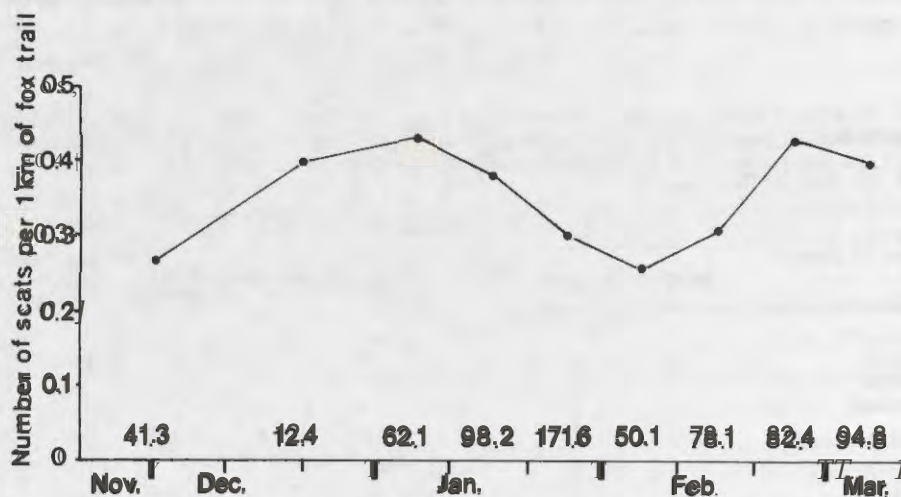


Fig. 1. Seasonal changes in the intensity of scat depositing by foxes during winter. Figures at the bottom indicate number of kilometers of fox trail for which each mean value was calculated.

Intensity of marking of forest trails by urine was higher in the second half of winter (after January 15) than at the beginning of winter (Fig. 2). Intensity of urine marking, calculated according to data from Fig. 2 for the first and second half of winter (3.56 and 4.99, respectively), was statistically different ( $t = 5.57, 0.01 \geq p > 0.0001$ ). On the other hand, intensity of marking of field trails was similar (Fig. 2) during the whole winter season. Forest trails were more frequently marked by urine than the field ones (4.72 and 4.00 urine marks per 1 km of trail, respectively). Though for the whole winter season this difference was not statistically significant ( $t = 1.06, 0.4 \geq p > 0.33$ ), for the second half of winter alone the mean frequency of marking (4.99 urine marks per 1 km of trail for the forest and 3.85 marks for fields) was statistically different ( $t = 4.99, 0.01 \geq p > 0.001$ ). In case of scat marking the difference between forest and fields was not significant (0.36 and 0.33 scats per 1 km of trail,  $t = 0.45, 0.7 \geq p > 0.6$ ).

#### Sex differences in intensity of trail marking

It was difficult to recognize sex of all followed animals but in more than ten cases the sex was determined (by the location of urine on the trail), so it was possible to compare intensity of marking among sexes. These data were not collected regularly, and the results do not represent the whole winter season. Males which were trailed on total distance of 34.3 km, marked their trails with intensity of 5.7 urine marks per 1 km. Females urinated with frequency of 4.2 times per 1 km of trail (total distance of trailing females was 23.3 km). Faeces were deposited with mean frequency of 0.39 and 0.56 per 1 km of trail by males and females, respectively. Unfortunately, the distance for which females and males were trailed, was insufficient for statistical verification of the results.

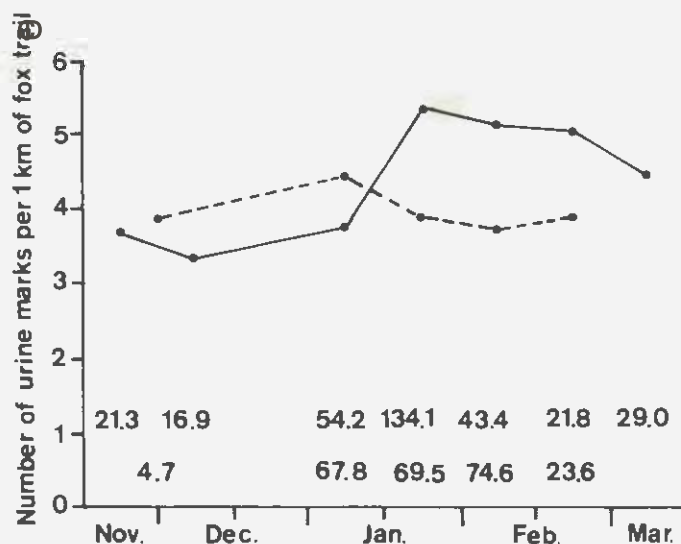


Fig. 2. Seasonal changes in the intensity of urine marking in the forest area (solid line) and in fields (dashed line). Figures at the bottom as on Fig. 1. Upper row for the forest and lower for fields.

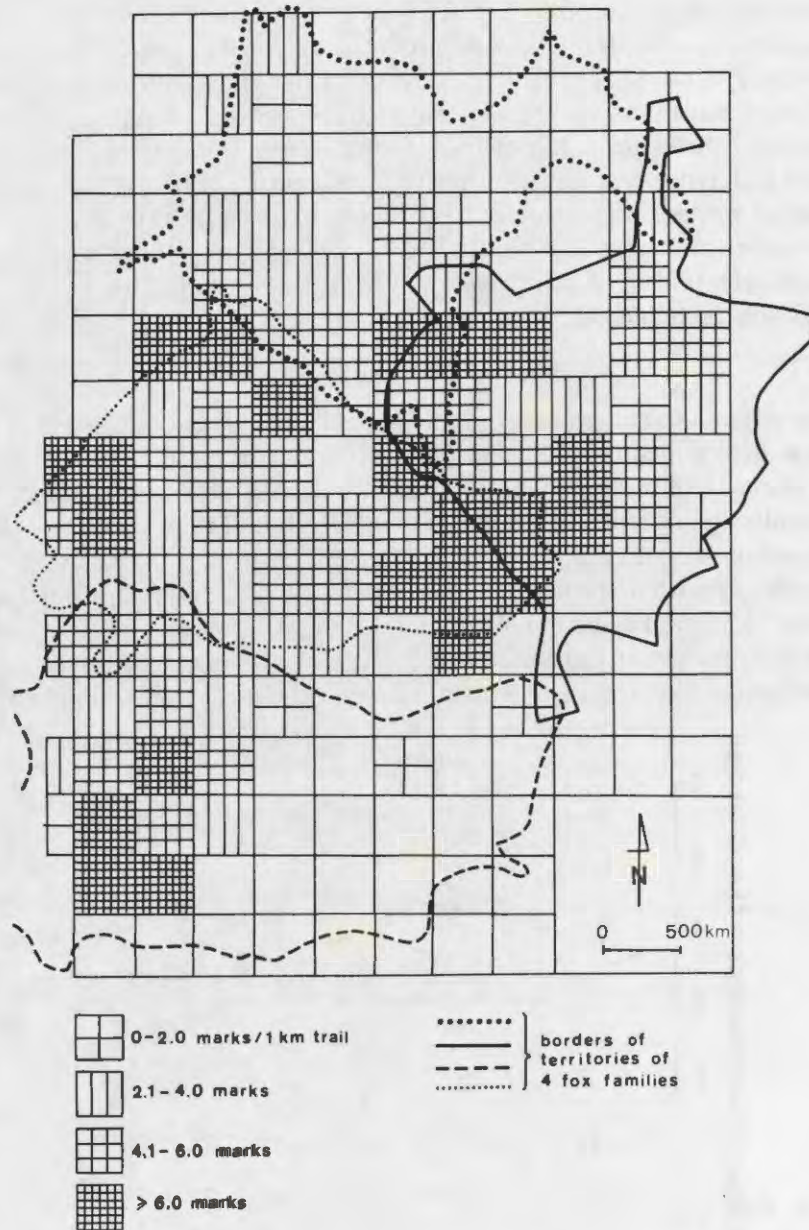


Fig. 3. Intensity of territory marking (ITM) by foxes. Borders of territories of four families after Goszczyński (1989 b).



Females deposited 14 of their urine marks on permanent objects, 79 on undurable objects and 6 on intermediate ones. For males the respective values were: 99.71 and 27 urine marks. Percentage analysis revealed that males left more marks than females on permanent objects (50.3% versus 14.1%,  $d = 6.04$ ,  $p \leq 0.001$ , test for comparison of two percentages) like trunks, posts, knolls and so on. Females more frequently than males marked flat surfaces of snow (33.3% versus 8.1%,  $d = 4.98$ ,  $p \leq 0.001$ , test for comparison of two percentages).

#### Intensity of territory marking

Among analysed squares, mean intensity of marking (*ITM*) varied widely: from 1 to 8.7 urine marks and from 0 to 11.95 scats per 1 km of fox trail. For an average square, intensity of marking was estimated on  $4.1 \pm 1.8$  (SD) urine marks and  $0.36 \pm 0.34$  (SD) faeces per 1 km of trail.

Intensity of home range marking (*IHRM*) estimated for separate squares varied from 0.05 to 11.42 urine marks per 1 ha per 24 hrs (mean  $\pm$  SD for all squares  $0.43 \pm 0.26$  SD) and from 0 to 0.28 scats per 1 ha per 24 hrs (mean  $0.04 \pm 0.05$  SD).

Squares located near territory borders or in the overlapping parts of territories of two families were marked with similar intensity as squares located in the territory interior. It was shown by values of both indices: *ITM* and *IHRM*. Some areas of exceptionally intensive marking could be found as often in the territory centre as on its borders (Fig. 3). "Forest" squares were slightly more frequently marked than "field" ones but the difference was not statistically significant as determined by t-Student test ( $t = 1.55$ ,  $0.22 > p > 0.1$ ).

Intensity of area searching by foxes ( $A_f$ ) and intensity of territory marking (*ITM*) assessed for each square were not correlated ( $r = 0.11$ ,  $0.42 > p > 0.033$ ). There was also no correlation between intensity of trail marking by urine and faeces and the number of fox shelters and burrows present in a given forest square ( $r = 0.17$ ,  $0.32 > p > 0.2$ ). Weak correlation, however, was found between intensity of area searching by rodents ( $A_R$ ) and *ITM* ( $r = 0.33$ ,  $n = 61$ ,  $0.05 > p > 0.001$ ). This correlation indicates that the fox trails crossing areas abundant in rodents were marked more frequently.

#### Discussion

Foxes living in different habitats probably use different types of objects for marking, according to relative abundance of these objects in particular habitat. Nevertheless, the frequent marking of undurable objects, in this study, is worthy of notice. Foxes, especially females, readily marked pine twigs fallen to forest floor, sticks, litter and leaves dug out from under the snow by ungulates, and straw scattered by the wind on fields. It was also observed that foxes urinated on old gloves or plastic bags discarded by forest workers, and on rodent traps set in the forest. Marking of such objects is probably a form of familiarizing with new elements appearing in a habitat.

Deposition of urine on new objects indicates great plasticity in fox marking behaviour, but it can serve at the same time as territory marking.

From 70 % to 80 % of all urine marks were deposited on vegetation, knolls, barks, posts and similar objects raised above the ground surface. Placing the urine marks on such objects enhanced the diffusion of scent and enlarged the range of its influence. Faeces, however, were more frequently than urine marks, deposited on flat surfaces of snow. This observation denies current opinion that predators leave their seats preferably in well exposed sites. It is contradictory to Maedonald's (1980) statement that "...red fox faeces are almost exclusively left on or near visually conspicuous objects".

Carrion found by foxes, captured prey and killing sites were frequently marked, although marks deposited on such objects accounted only for 5 % of all urine marks and for 16 % of scat marks. As was stated above, the intensity of marking was correlated with abundance of rodents but the correlation was rather weak. Very strong correlation between density of field vole, *Microtus arvalis* and intensity of scent marking was observed in agricultural areas of western Poland in Wielkopolska region (Ryszkowski *et al.* 1973). However, in these areas field voles were much more abundant than in Central Poland. Correlation between frequency of rodent hunting and intensity of marking was also pointed out by Korytin (1979).

On the basis of data presented here and published earlier, it was possible to estimate a success of fox hunting for rodents. If average distance covered by fox in 24 hours was assumed to be 13.8 km (Goszczyński 1989b) and average number of attacks for rodents for 1 km of fox trail was assumed to be 3 (this paper) then 44.4 fox attacks for voles and mice per 24 hrs resulted. Further it was assumed that fox food requirements was approximately 470 g (wet weight) of food daily (Ryszkowski *et al.* 1973), that the rodents in predator diet in this area formed 28.4 % by weight (Goszczyński 1989b) and that the average body mass of a rodent was 20 g. Then it could be calculated that a fox captured approximately 6.7 rodents per 24 hrs. Comparison of this value with number of attempted attacks approximates hunting success at 16%. The same calculation made for western Poland gave a similar result of 22% (according to data of Ryszkowski *et al.* 1973, and Goszczyński 1974).

Winter tracking of foxes revealed that sites of successful hunting for rodents and the sites of hunting with unknown result, were marked with similar intensity. However, the majority of sites on which foxes hunted with success were left unmarked. In case of carrion found or visited by predators and marked by them, the act of marking was not correlated with the amount of food it could provide. These observations, and also those of Korytin (1979) who demonstrated that foxes more quickly recovered the caches of food previously marked, don't agree with Henry's (1977) hypothesis. Henry stated that foxes marked with urine mostly those sites from which food had already been eaten but odour of food remained. In other words, urine marks would prevent the fox from intensively searching these sites in the near future.

On the basis of observations from this study it would seem that foxes urinated



mainly on sites with attractive smell. The accumulation of urine marks in some places, e.g. in fields with abundant rodents, may incline the predator to more intensively search the area.

The established frequency of marking of trail by foxes may be slightly underestimated. This concerns mainly the cases when foxes marked snow-free parts of trunks. Fox urine odour, though detectable for people for few days, may be a remain of previous marking. So it is difficult, on the basis of an odour alone to set precisely date of the scent marking. In spite of these reservations, intensity of marking estimated in this paper was similar to Korytin's (1979) results. He estimated intensity of urine marking on 6.5 marks per 1 km of trail for males and on 4.3 marks for female. Slightly lower frequency of marking was noted on agricultural areas in western Poland by Ryszkowski *et al.* (1973). In that region, predominance of open fields and frequent strong winds made the registration of all scent marks difficult. Higher frequencies of marking noted for hand-reared foxes by Lloyd (1980) and Macdonald (1980) could result from short periods, for which the animals were released from enclosures.

Data on frequency of defecation given in the present paper comply with the results reported by different authors from various geographical areas; 0.2 to 0.6 seats per 1 km of fox trail (Korytin 1968, 1979, Per-Olof 1970, Ryszkowski *et al.* 1973). Low frequency of defecation observed at the beginning of winter resulted probably from decrease in food availability. The first snow, coming usually at the end of November or beginning of December, reduced the chances for successful hunting of rodents. Moreover, at this time of year the good condition of hares and lack of carrion of roe deer or wild boar, limited food supply for predators. Distinct decrease in defecation in first 10-day period of February coincided in time with the rut season of foxes in the studied area (see also Goszczyński 1989a). Temporary decrease in food consumption, and as a consequence in frequency of defecation, was probably a behavioural reaction of males searching for mates.

Increase in urine marking activity observed in forest in the second half of winter could also be caused by the rut. Such was the explanation of increased frequency of urine marking given by Korytin (1979). However, high activity of marking did not disappear after the rut, and lasted, at the same level, up to the end of winter. In addition, no changes in urine marking activity was observed in field trails. So, alternative explanation is that foxes more frequently marked an area in the vicinity of the den when time of parturition approached. It is possible that after fox mating these marks played an important role in territory defense.

Comparison of frequencies of urine and scat depositing and their variability, indicated greater importance of urine in olfactory communication. The results for the whole winter season did not reveal any difference between frequency of marking on border and inner part of the territory, although there was a tendency toward depositing the marks in certain places within the territory. Slightly higher frequency of marking forest trails resulted from the increase of marking activity in this area toward the end of winter (Fig. 2).

The obtained results do not give an unequivocal answer to the question, whether scent marking plays an important role in territory defence and preserves the patterns of space division. High marking activity observed in the forest in the second half of winter seems to support such interpretation. Also the fact that the males which are responsible for territory maintenance marked more frequently durable objects, indicates the significance of such marking for territory defence. Perhaps scent marking only supports vocal and visual signalization. This was the interpretation given by Sargeant (1972) to explain the fact that empty territories were very quickly grabbed by neighbours. Importance of vocal signalization in the maintenance of territory was also pointed out by Burrows (1968). It seems that this problem needs to be resolved by specially designed field experiments, and simple field observations of marking activity will not provide an answer to this question.

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