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SHORT COMMUNICATION

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The importance of crossroads in faecal marking behaviour of the wolves (*Canis lupus*)

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Abstract For wolves (*Canis lupus*) scats play an important function in territorial marking behaviour. Depositing scats at strategic sites such as crossroads and on conspicuous substrates probably increases their effectiveness as visual and olfactory marks. It is therefore likely that scats will be deposited, and will accumulate, at particular crossroads where the probability of being detected by other wolves is greatest. To check this hypothesis, a wolf population in NW Spain was studied for two consecutive years, from May 1998 to March 2000, and the spatial distribution of 311 scats detected along roads (both at and away from crossroads) was analysed. This study was conducted over an area of 12,000 ha in Montes do Invernadeiro Natural Park. The results confirm that wolves preferably deposit their scats at crossroads (60.1%) and on conspicuous substrates (72.1%). Significantly more scats were found at intersections with numerous, easily passable roads connecting distant territories. Thus, wolves preferably deposit their faeces at crossroads with high accessibility and driveability. The larger the surface area of the crossroads, the more scats were found. Crossroads are therefore highly strategic points that facilitate the detection of scats.

Introduction

A number of studies have shown that chemical communication plays a significant role in the social organisation and spatial distribution of the wolf (Mech 1970; Peters and Mech 1975; Rothman and Mech 1979). Wolves mark their territories with urine and secretions from their anal and interdigital glands (Peters and Mech 1975; Fox and Cohen 1978; Asa et al. 1985). The use of urine as a scent source has long been known. Several authors indicate that scats may also be used by wolves for marking their territory (Peters and Mech 1975; Asa et al. 1985), although this is less clear than urine marking since no conspicuous or specific posture is adopted. A communicative function can be attributed to scats when they are deposited at conspicuous or raised sites (Kleiman 1966), or when they accumulate in strategic places, where the probability of their detection by other individuals is at a maximum. This behaviour has been observed in red fox (*Vulpes vulpes*) (Macdonald 1980) and Iberian lynx (*Lynx pardinus*) (Robinson and Delibes 1988). These species deposit a great number of scats at crossroads; huge piles can develop that, in some cases, can be considered as more or less diffuse latrines (Macdonald 1980).

When scent marks are deposited at prominent sites, they can serve both orientative and social functions (Alberts 1992). Conspicuous and elevated sites can enhance the visual component of these marks (Vilà et al. 1994).

Although people accustomed to coming across wolves in the countryside know that crossroads are good places for locating their tracks, their scat marking behaviour at crossroads is insufficiently well documented. This paper reports the importance of crossroads in marking with scats. The spatial distribution of wolf scats in NW Spain was examined, and the number of scat depositions at crossroads and along other parts of the road compared. Variables were sought that might influence the selection of particular crossroads for scat deposition.

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Materials and methods

This study was performed over an area of 12,000 ha in the Montes do Invernadeiro Natural Park, NW Spain. This craggy region consists of a series of low mountains and deep valleys. The study

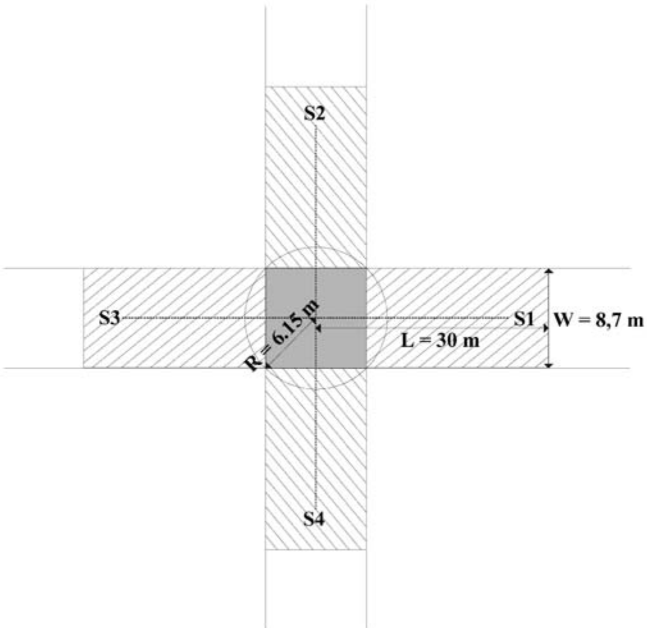

Fig. 1 Outline of a typical crossroad in the study area and the variables considered. *Grey area* denotes the surface area of crossroads, *lined area* the surface area of the periphery of crossroads, and *white area* the rest of road; S_n is the number of roads leaving from the centre of the crossroads

area is crossed by a dense network of firebreaks and forestry roads, which are frequently used by wolves in their travels.

The study was conducted from May 1998 to March 2000. Over this period a total of 14 surveys were made (2–3 days each). The mean distance inspected in each survey was 59.8 km. Maps with 1 km^2 cells (UTM) were used to record scat positions. During the surveys, a total area of 837.2 km was surveyed: unsurfaced roads (515.5 km), asphalted roads (150.4 km), wide firebreaks used as roads (149.9 km) and firebreaks (21.3 km).

To check whether the wolves showed any preference for using crossroads as scat deposition sites, scat frequencies at crossroads, the periphery of crossroads, and the remaining parts of roads were compared. The density of crossroads in the study area was 0.9 crossroads per kilometre.

A crossroads was defined as the area resulting from the intersection of two or more roads (Fig. 1). The complexity of these crossroads varied in terms of the number of roads leaving from its centre. A total of 99 crossroads were surveyed, although not all were reviewed in each survey. The total distance surveyed for scats with respect to the 'interior' of the crossroads (T_C) (Fig. 1) was calculated according to the following general formula: $T_C=W\ \Sigma U_n$, where W is the mean width of the different roads in the study area and U_n is the total number of crossroads of each type in the sample.

Bearing in mind that the probability of a wolf entering a crossroad is higher than its passing any given point of any road eventually forming it, the following correction coefficient was used to calculate the expected scat frequency at the crossroads: C=1/2S, where S is the number of roads leaving the intersection. The formula used to calculate the distance surveyed at the crossroads was therefore $T'_C=1/2W\ \Sigma S_n U_n$ (applying the corresponding correction coefficient).

It was considered that a scat had been deposited at a crossroads when the distance to its centre was less than or equal to the radius (R) of the circumference marking the area of the crossroads (Fig. 1) [the mean width of the roads (W) was 8.7 m, R=6.15 m].

The distance to the centre of the crossroads for all scats deposited closer than 30 m from it was measured. The area between the borders of the crossroads and the 30 m that surrounded them was termed the "periphery of the crossroads" (Fig. 1). The complete periphery of the crossroads was always checked. To estimate the expected frequency of finding a scat, the total distance of the crossroad peripheries surveyed was calculated according to the following formula: $T_P=(L-1/2W)\Sigma S_n U_n$. In this study, L=30 m (Fig. 1).

The total distance surveyed of the remaining parts of the roads (T_R) was calculated as the difference between the total distance surveyed minus the distance surveyed at the crossroads and their peripheries: $T_R=T_T-(T_C+T_P)$.

To check whether the wolves selected certain crossroads, and to determine what characteristics influenced this selection, the following crossroad variables were considered:

Complexity
: the number of roads leaving the crossroads. The correction coefficient (C) was used to calculate the expected and observed scat frequencies.

Type
: the kinds of roads that formed the crossroads (asphalted roads, unsurfaced roads and firebreaks).

Surface area
: including the periphery of the crossroads.

Altitude
: of the crossroads.

Accessibility
: (defined in terms of the roads leaving the intersection). The accessibility of a road was established according to its importance as a line of communication or in terms of the areas it connected. The values assigned were either 3 (high accessibility: when the ends of the roads connected large areas, e.g. two mountains or two valleys), 2 (medium accessibility: e.g. when the roads that formed the intersection were open but connected areas of secondary importance), or 1 (low accessibility: e.g. when one or more of the roads stopped at a "barrier" such as a reservoir, a fence, a village or simply petered out in the mountains).

Driveability
: (defined in terms of ease with which the roads forming the crossroads could be travelled). The following values were assigned: high driveability (3), i.e. when a car could travel the roads easily (generally firm, flat roads without obstacles); medium driveability (2), i.e. when due to its rugged surface only 4-wheel drive vehicles could travel it; and low driveability (1), i.e. those roads that could not be travelled (or were extremely difficult to travel) with any vehicle (because of invasive vegetation, rocks in the road or too steep a slope).

Final values for accessibility and driveability were assigned to all crossroads. However, since crossroads may be formed by roads of different accessibility and driveability, the following criteria were used to assign final values: (a) when the roads forming the crossroads were of identical value, this was taken as the final value, (b) in crossroads formed by roads of two different values, the lower value was assigned, and (c) when crossroads were formed by more than two roads, only those with the two highest values were considered, and then the lower of these was assigned.

Results

During the study, 311 scats were found. Scat number/km was greater on the crossroads (8.30) than at their periphery (1.67) and fewer scats were found along other parts of the road (0.15). The number of scats detected at the crossroads and at their periphery was greater than would be expected for samples distributed at random (Table 1) (χ^2=1.170, df=2, P<0.001).

Table 1 Expected and observed frequency of scats in the three areas: crossroads, periphery of crossroads, rest of roads, and the distance surveyed in each

	Observed frequency	Expected frequency	Kilometres surveyed (real)	Kilometres surveyed (corrected)
Crossroads (T_C)	67	4.86	8.07	13.17
Periphery of crossroads (T_P)	120	28.67	77.64	77.64
Rest of roads (T_R)	124	277.47	751.48	751.48
Total (T_T)	311	311	837.20	842.29

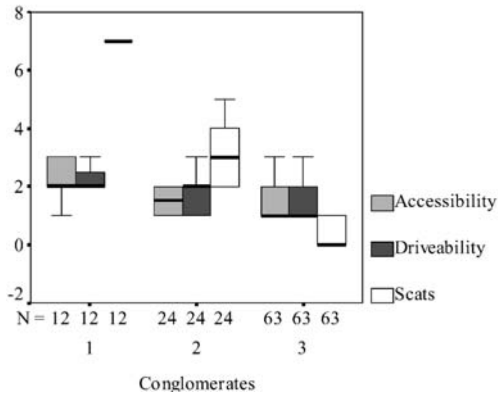

Fig. 2 K-Means conglomerate analysis for the following variables: accessibility (*grey boxes*), driveability (*black boxes*) and number of scats (*white boxes*)

Significantly more scats were found in the cells with greater numbers of crossroads (r_s=0.35, P<0.01). A significant negative correlation was observed (r_s=–0.68, P<0.001) between scat number and the distance to the centre of the crossroads. Nevertheless, 57.8% of scats were located between 2 and 10 m from the centre.

At the crossroads and at their peripheries, the scats were deposited mainly on conspicuous or high substrates (72.1%), but along the rest of the road this decreased to 45.6% (χ^2=20.4, *df*=1, P<0.001).

The average number of scats accumulated at three-exit road crossroads (simple crossroads) and four-(or more) exit road crossroads (multiple crossroads) was 3.2 and 5.7, respectively (χ^2=16.5, *df*=1, P<0.001).

All the 99 surveyed crossroads were analysed. The distribution of the scats at the different crossroads was not random. Thus, the scat number was not correlated with the altitude of crossroads (r_s=–0.02, P>0.05). However it was correlated with other variables such as accessibility (r_s=0.33, P<0.01), driveability (r_s=0.35, P<0.001) and, to a lesser extent, the surface area of the crossroads (r_s=0.20, P<0.05). The type of crossroads had no influence on this selection (χ^2=13.9, *df*=21, P>0.05).

To classify the crossroads into similar groups, a K-Means conglomerate analysis was performed for accessibility, driveability and number of scats (Fig. 2). Accessibility and driveability were scored from 1 to 3 and the number of scats from 0 to 7. The 12 crossroads of conglomerate 1 showed high accessibility (2.17), high driveability (2.08) and a high number of scats (6.83). The 24 crossroads of conglomerate 2 showed intermediate accessibility (1.50), driveability (1.75) and number of scats (3.21). The rest of the crossroads in the sample (63), contained in conglomerate 3, showed low accessibility (1.33), low driveability (1.37) and few scats (0.30). The differences among the three conglomerates were statistically significant for all three variables: accessibility (χ^2=23.8, *df*=4, P<0.001), driveability (χ^2=15.9, *df*=4, P<0.01) and number of scats (χ^2=198.0, *df*=14, P<0.001).

Discussion

The results show that wolves moving along roads select intersections for depositing their scats. Since crossroads are multidirectional, scats placed at them have a higher probability of being detected: wolves can reach these points from different directions and are therefore more likely to encounter them. Scats deposited at crossroad peripheries can also be detected more easily than along the rest of road due to their proximity to the crossroad itself. In the present study, the more roads leading to a crossroad, the more scats were deposited there by wolves. The ultimate selection of a crossroad depended on its complexity, driveability, accessibility and, to a lesser extent, on its surface area.

The selection of conspicuous substrates at crossroads results in an amplification of the visual component of any deposited scat, increasing its effectiveness as a warning signal. Kleiman (1966) reported the deposition of scats on conspicuous substrates to increase their effectiveness in areas of high strategic value.

The wolves selected the crossroads that were more accessible, depositing a greater number of scats at those that allowed access to different mountains and areas of special importance inside their territory, such as the rendezvous site. However, crossroads with low accessibility were hardly marked at all – the probability that any marks left would be detected would have been lower since the wolves hardly ever used such roads. Wolves therefore optimise the distribution of their scats by placing them at crossroads with very well-defined characteristics.

The wolves of the present study repeatedly marked certain crossroads. Peters and Mech (1975) also observed how the wolves of one pack repeatedly marked the same crossroads. Wolves would be attracted by the scent of previously deposited scats, and this would facilitate the deposition of new scats. During their travels, wolves would stop more often and spend more time at these points of maximum scent concentration in order to investigate previously deposited scats. They would be stimulated to mark over previous marks, so that at certain crossroads and on certain substrates at these sites, latrines with a high numbers of scats would form. Macdonald (1980) indicates that faeces of some carnivores accumulate in certain places, forming diffuse latrines.

The more profusely marked crossroads were far away from each other. Moreover, these were located at the tops of mountains where scent would spread better, creating a scent barrier against intruders. Wolves concentrate their marks at the limits of their territory, mainly at those borders where the risk of intrusion is greater (Peters and Mech 1975). The scent-marking of the crossroads near to the territorial frontiers probably guarantees the detection of the marks by intruders.

Finally, it is worth noting that since crossroads act as scat accumulation points, they also provide decisive spatial references of the presence of wolves. Knowing the distribution of wolves and their population size (which requires indirect methods of study) is essential to guarantee their conservation. Crossroads, which can be rich in scats, could provide extraordinarily valuable material for non-invasive studies requiring the extraction of DNA (Wayne and Vilà 2003) and glucocorticoids (indicative of stress levels) (Creel et al. 2002).

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