POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	57	3	605–609	2009

Short research contribution

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SPATIAL DISTRIBUTION OF SCENT MARKS IN THE RED FOX (*VULPES VULPES* L.): DO RED FOXES SELECT CERTAIN PLANTS AS SIGNAL POSTS?

ABSTRACT: Chemical signals are widely used in inter and intraspecific communication in many animals. The importance of scent marks in communication has led to a variety of strategies in animals to increase the detectability and persistence of their scent marks.

We studied the scent marking of foxes in relation to the role of plants as scent posts in a suburban Mediterranean forest in Madrid. Twice a month, from October 2005 to April 2006, we prospected 16 fixed 50 × 50 m plots, randomly distributed along the study area. We registered all fox faeces and their association to different plants, as well as the potential availability of the different plant species in our study area. Our results indicate that faeces were associated with plants mainly in the clearings, foxes preferred wooden species to grasses as scent posts and holm oak shrubs and rockroses to other wooden species. These data suggest that red foxes select certain plants as substrates for their faeces and pose the possibility that they are guided by searching images when looking for scent posts.

KEY WORDS: chemical communication, red fox *Vulpes vulpes*, scent marking, territorial behaviour

Many organisms generate stable structures that reduce the cognitive complexity of their environment (Chandrasekharan and Stewart 2004). By means of these structures or labels animals can make the environment much more predictable, reducing in this way their uncertainty. The nature of these labels closely depends on the sensorial abilities of the animals. In mammals, mainly nocturnal or crepuscular animals, chemical marks often play an essential role (Kleiman 1966, Ralls 1971, Johnson 1973) as environmental labels.

Scent marks in mammals can perform many functions (Kleiman 1966, Eisenberg and Kleiman 1972, Henry 1976, Brown and Macdonald 1985, Halpin 1986, Wirant and McGuire 2003, Kavaliers *et al.* 2005), being the territorial defence one of the most commonly accepted (Gosling 1982). Due to the great importance of the marks in the transmission of information, animals should increase the probability that other animals detect them, what implies both to enhance the conspicuousness of the marks and guarantee its durability. In this sense, compared to urine and glandular secretions, faeces constitute composite marks since they add a visual component to the chemical one, increasing in this way the probability of its detection (Alberts 1992).

Animals can improve even more the detectability of the marks by choosing both the most suitable location and the best substrate for them. Conspicuous substrates such as stones, sticks, soil elevations, faeces and other animal remains, anthropogenic elements and plants could be suitable as signal posts (Goszczyński 1990, Monclús and Miguel 2003a, b; Monclús *et al.* 2008).

There is some evidence in mammals about differential selection of plants as substrates for marking (Burst and Pelton 1983, Schaller *et al.* 1985, Clevenger and Purroy 1991, Barja 1996, Barja and Miguel 2000). Selection of plants for marking could depend in some cases on the availability of plant species, as seems to be the case of rubbing by black bear (*Ursus americanus* Pallas) in Great Smoking Mountains National Park (Burst and Pelton 1983) and urine marking by Barbarian lions (*Panthera leo leo* L.) and Siberian tigers (*Panthera tigris altaica* Temminck) in Madrid Zoo (Barja 1996). Other factors could also be important. So, Schaller *et al.* (1985) proposed that selection of conifers for anogenital marking by giant panda (*Ailuropoda melanoleuca* David) could be due to its rough bark, where scent would adhere better, while both white-tailed deer (*Odocoileus virginianus* Hall) and Alaskan moose (*Alces alces* L.) select aromatic species of trees for rubbing (Kile and Marchinton 1977, Bowyer *et al.*1994, respectively). Indeed, Barja and Miguel (2000) found that Iberian wolves (*Canis lupus signatus* Cabrera) in Madrid Zoo urinated mainly in the trees with a thicker trunk.

All these findings suggest that plants could be suitable signal posts, at least for marking with urine and glandular secretions. However, preferent association of faeces with certain plants is scarcely described. Barja *et al.* (2001) observed that red foxes (*Vulpes vulpes* L.) in Galizia (North Spain) marked with faeces wooden plants in a greater extent than herbaceous ones, possibly due to the perennial character and greater height of wooden plants, that could make them more attractive and effective as signal posts.

In the present study we want to explore the association of faeces and plants in the case of red fox, a species that do a sustained effort in marking its home range (Macdonald 1979, 1980). We will deal with the possible selection of plants as scent posts by red foxes and its connection with the spatial distribution of the marks. We expect: 1) selection of plants will be higher in the clearings, since accessibility is higher for clearings than for roads; 2) foxes will select those plants more conspicuous, independently of its availability

The study was carried out in a Mediterranean forest in Madrid, Central Spain (300 ha, 700 m a.s.l.), close to important human population nuclei. The forest mass is constituted mainly by holm oaks (*Quercus ilex ballota* (Desf.) Samp.) with interspersed pine plantations (*Pinus pinea* L. and *Pinus pinaster* Aiton). The scrub is typically Mediterranean and constituted by rockrose (*Cistus ladanifer* L.), *Halimium umbellatum* L. (Spach), thyme (*Thymus zygis* L.), tall wormwood (*Artemisia campestris* L.) and French lavender (*Lavandula stoechas pedunculata* (Miller) Samp.).

We used 16 fixed 50 × 50 m plots, randomly distributed along the study area. Twice

Table 1. Mean availability (measured as a percentage) of roads, clearings, wooden and herbaceous species in the plots, and number of scats associated to them.

Location	Mean availability	Scats localization	
		N	%
Roads	6.8±9.9	42	18.8
Clearings	41.5±24.7	182	81.3
Wooden species	51.7±22.3	33	14.7
Herbaceous species	0.7±1.2	10	4.5
Holm oak	40.2±22.4	20	8.9
Rockrose	9.7±12.5	10	4.5
Halimium	1.7±4	3	1.3

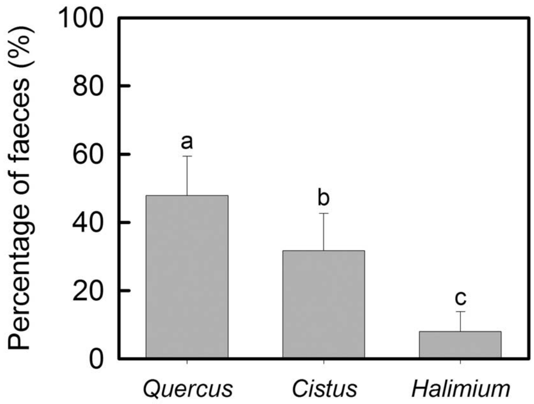

Fig. 1. Proportion of fox faeces associated to the different species of wooden plants. Different letters indicate significant differences between groups. See text for statistics.

a month, from October 2005 to April 2006, we prospected the plots searching for fox faeces. For every faecal sample we recorded:

- its association/no association to plants (we considered association occurred when a faeces was deposited close to a plant (≤0.5 m) or on it.
- its location in a clearing or in a track (we considered as roads every path, independently of its width, and as clearings, the clears in the wood and the intersections).
- the kind of plant: wooden/herbaceous
- the species, in the case of wooden plants

Within each plot we measured as a percentage the availability of a) roads and clearings, b) wooden and herbaceous species (measured at 1 m above ground level) and c) main wooden species (*Quercus ilex*, *Cistus ladanifer* and *Halimium umbellatum*). We considered that this measure could represent a better approximation to the perception of the environment by foxes than the number of individual plants. The proportion of faeces in roads and clearings and associated to plants (Table 1) was corrected according to the observed availability. With the values obtained, we calculated the expected frequencies of occurrence of the associations, considering a regular distribution of the fox faeces in the plot.

Our data did not follow a normal distribution and independence of the data was not guaranteed (faeces could belong to the same fox or foxes), thus we used non-parametric analysis for dependent samples (Wilcoxon test). All analyses were performed in SPSS 15 (SPSS Inc., Chicago, Il., USA).

From 224 faeces we found, 28% were associated to plants. 87% of the faeces associated to plants were deposited in clearings, whereas 13% were in roads. The differences were significant ($Z = 3.058$; $P < 0.01$).

Foxes significantly preferred wooden plants (75%) to herbaceous ones ($Z = 2577$; $P = 0.01$). Concerning wooden plants, 52% of faeces were associated to holm oaks, 39% to rockroses and 9% to *Halimium umbellatum* (Fig. 1). Holm oaks were not significantly preferred to rockroses ($Z = 6.888$; $P = 0.49$), although both holm oak and rockroses were preferred to *Halimium* ($Z = 2.347$; $P = 0.02$; $Z = 1.985$; $P < 0.05$; respectively).

The transmission of information by means of chemical communication is crucial for many animals, playing a decisive role in the biological success of the individuals (Dawley 1984, Gabor and Jaeger 1995). For this reason, marks should be deposited in those places where could be easily detected by other individuals (Gorman and Trowbridge 1989). Since more than 28% of faeces were placed close to or onto plants it could be inferred that marking of plants provides some advantage to foxes.

The association of faeces to plants was significantly higher in clearings than in roads. Plants are conspicuous and provide a permanent support for marks. As we expected, association of faeces to plants was higher in clearings (more accessible) than in roads, what would favour the detection of faeces.

Our results also show that certain types and species of plants were preferred as signal posts. Wooden plants were more profusely marked than herbaceous ones, which agree with the results obtained by Barja *et al.* (2001) in Galizia. Amongst the wooden plants, holm oaks shrubs and rockroses were the species more frequently marked, being *Halimium* specimens less marked than expected. Since *Halimium* is less abundant in the area than holm oaks and rockroses, probably the foxes in the area do not have a searching image for *Halimium* as consolidated as for the other species. Although as a *Halimium umbellatum* could represent a discontinuity in the environment that might attract foxes, it seems that holm oaks and rockroses constitute more powerful stimuli, either visual or chemical. Both rockroses and *Halimium umbellatum* exude laudanum, a fragrant, sticky gum used in perfumery as a fixative (Polunin 1991), but the very pervasive odour of rockroses (clearly detectable for humans) probably represents a stronger attractor. More functional and, certainly, less parsimonious explanations concerning differential selection of wooden species would require experimental procedures. Furthermore, social explanations cannot be discarded. Association of faeces with plants could be simply the result of fox responses to faeces left by other foxes but would not explain original associations.

Our data provide further information about fox marking behaviour as well as of the way that foxes perceive their environment and are attracted to conspicuous stimuli, what could be used in field research. Similar studies could allow, for instance, gain knowledge about the best placements for scent stations and automatic cameras in those carnivore species where these techniques constitute an already consolidated method of study.

ACKNOWLEDGEMENTS: We want to express our gratitude to Comunidad Autónoma de Madrid that gave us the permissions necessary for the accomplishment of this study. We are grateful to Paloma Chaves, Isabel Barja, Anna Hillbricht-Ilkowska and an anonymous reviewer for their helpful suggestions in earlier drafts.

REFERENCES

Alberts A.C. 1992 – Constraints on the design of chemical communication systems in terrestrial vertebrates – Am. Nat. 139: S62–S89.

Barja I. 1996 – Estudio comparado del comportamiento en cautividad de leones del Atlas *(Panthera leo leo*) y tigres siberianos *(Panthera tigris altaica*) – Memoria de licenciatura. Universidad Autónoma de Madrid (in Spanish).

Barja I., Miguel F.J. 2000 – Señalización olorosa y visual del lobo ibérico (*Canis lupus signatus* Cabrera, 1907) en el Zoo de Madrid – Galemys, 12 (número especial): 27–35 (in Spanish).

Barja I., Miguel F.J., Bárcena F. 2001 – Distribución espacial de los excrementos de zorro rojo (*Vulpes vulpes*, Linnaeus 1758*)* en los Montes do Invernadeiro (Ourense) – Galemys, 13 (número especial): 171–178. (in Spanish).

Bowyer R.T., Ballenberghe V., Rock K. 1994 – Scent marking by Alaskan moose: characteristics and spatial distribution of rubbed trees – Can. J. Zool. 72: 2186–9192.

Brown R.E., Macdonald D.W. 1985 – Social odours in mammals. Clarendon Press, Oxford.

Burst T.L., Pelton M.R. 1983 – Black bear mark trees in the Smoky Mountains. International Conf. Bear Res. and Manage. 5: 45–53.

Chandrasekharan S., Stewart T. 2004 – Reactive agents learn to add epistemic structures to the world (In: Proceedings of the 26th Annual Meeting of the Cognitive Science Society, Eds. K.D. Forbus, D. Gentner, T. Regier) – Chicago, Hillsdale, NJ: Lawrence Erlbaum, pp. 198–203.

Dawley E.M. 1984 – Recognition of individual, sex and species odours by salamanders of the *Plethodon glutinous-P. jordani* complex – Anim. Behav. 32: 353–361.

Eisenberg J.F., Kleiman D.G. 1972 – Olfactory communication in mammals – Annu. Rev. Ecol. Syst. 3: 1–32.

Gabor C.R., Jaeger R. 1995 – Resource quality affects the agonistic behaviour of territorial salamanders – Anim. Behav. 49: 71–79.

Gorman M., Trowbridge B.J. 1989 – The role of odor in the social lives of carnivores (In: Carnivore Behaviour, Ecology, and Evolution, Ed. J.L. Gittleman) – Vol. 1. Comstock, Cornell.

Goszczyński J. 1990 –Scent marking by red foxes in Central Poland during the winter season – Acta Theriologica, 35: 7–16.

Gosling L.M. 1982 – A reassessment of the function of scent marking in territories – Z. Tierpsychol. 60: 89–118.

Halpin Z.T. 1986 – Individual odours among mammals: origins and functions – Adv. Stud. Behav. 16: 39–70.

Henry J.D. 1976 – The use of urine marking in the scavenging behaviour of the red fox (*Vulpes vulpes)* – Behaviour, 61: 82–105.

Johnson R.P. 1973 – Scent marking in mammals – Anim. Behav. 21: 521–535.

Kavaliers M., Choleris E., Pfaff, D.W. 2005 – Recognition and avoidance of the odors of parasitized conspecifics and predators: Differential genomic correlates – Neurosci. Biobehav. Rev. 29: 1347–1359.

Kile T.L., Marchinton R.L. 1977 – White–tailed deer rubs and scrapes: spatial, temporal and physical characteristics and social role – Am. Midl. Nat. 97: 257–266.

Kleiman D.G. 1966 – Scent marking in the Canidae – Symp. Zool. Soc. Lond. 18: 167–177.

Macdonald D.W. 1979 – Some observations and field experiments on the urine marking behaviour of the red fox, *Vulpes vulpes* – Z. Tierpsychol. 51, 1–22.

Macdonald D. 1980 – Patterns of scent marking with urine and faeces amongst carnivore communities – Symp. Zool. Soc. Lond. 45: 107–139.

Monclús R., Miguel F.J. 2003a – Señalización y respuestas a intrusos en el zorro rojo *(Vulpes vulpes)* – Colección documentos de trabajo. UAM Ediciones. (in Spanish).

Monclús R., Miguel F.J. 2003b – Distribución espacial de las letrinas de conejo (*Oryctolagus cuniculus*) en el Monte de Valdelatas – Galemys, 15, 157–165. (in Spanish).

Monclús R., Arroyo M., Valencia A., Miguel F.J. 2008 – Red foxes (*Vulpes vulpes*) use rabbit (*Oryctolagus cuniculus*) scent marks as territorial marking sites – J. Ethol. 27: 153-156.

Polunin O. 1991 – Guía de campo de las flores de Europa – Ediciones Omega, Barcelona. (in Spanish).

Ralls K. 1971 – Mammalian scent marking – Science, 171: 443–449.

Schaller G.B., Jinchu H., Wenshi P., Jing Z. 1985 – The Giant Pandas of Wolong –The University of Chicago Press.

Wirant S.C., Mcguire B. 2004 – Urinary behaviour of female domestic dogs (*Canis familiaris)*: influence of reproductive status, location, and age – Appl. Anim. Behav. Sci. 85: 335–348

Received after revision December 2008