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Do Red Foxes (*Vulpes Vulpes)* Increase the Detectability of Scent Marks by Selecting Highly Conspicuous Substrates

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Abstract

In mammals, especially those that are nocturnal or crepuscular, chemical marks usually play a significant role as environmental labels. Scent marks in mammals can have many functions, including territorial defense and communication signals in the mating season. Furthermore, animals can increase the detectability of marks by selecting highly conspicuous locations and substrates on which to mark, such as stones and sticks, on or around faeces, other animal carcasses, anthropogenic features, and plants. Human-carnivore interactions can result in a conflict where perceived damage to livelihoods occurs in socio-economically poor areas. In the Shigar Valley, Karakorum Range, Pakistan, subsistence mixed farming is the predominant land use and red foxes (*Vulpes vulpes)* are widely persecuted. Understanding the effects of human activity and habitat factors on fox behaviors in the region are lacking. We used line transect surveys aided by a domestic dog (*Canis familiaris*) to detect fox faeces locations and characterize fox den form 2015-16-17. We encountered 467 fox scats by dog assistance. We tested for associations between scent deposition, and environmental variables including vegetation and substrate type, distribution of livestock carcasses and dung, roads and agricultural land at micro-habitat. We found more fox scats on aromatic plants, shrubs, and on or near livestock feaces and carcasses. Fox scent marking site selection varied for forested and shrub areas relative to open grassland or barren ground and vegetation cover and tree density at the microhabitat scale. The findings suggest that foxes do not avoid human activity *per se* and anthropogenic benefits (road kill, livestock carrion, crop food sources) may outweigh the costs of persecution. Foxes may also provide ecosystem benefits via seed dispersal, carrion removal and regulation of prey populations.

Keywords: Communications; Domestic dog; Single post; Territory marking

Introduction

In mammals, especially those that are nocturnal or crepuscular, chemical marks usually play a significant role as environmental labels [1]. Scent marks in mammals can play many functions [2], including territorial defense and communication signals in the mating season. Furthermore, animals can increase the detectability of marks by selecting highly conspicuous locations and substrates on which to mark, such as stones and sticks, on or around feces, other animal carcasses, anthropogenic features, and plants that may strengthen signaling potential [3]. However, associations between fecal marking site selection and vegetation type are infrequently explored or reported [4].

Barja, et al. [5], determined that red foxes (*Vulpes vulpes)* in Galizia, northern Spain, marked with the feacal matter around woody plants to a greater extent than herbaceous plants. Plant selection for scent marks appears to be important in the case of rubbing behavior by black bear (*Ursus americanus, Pallas, Burst and Pelton* [6], as well as for urine marking by Barbary lions (*Panthera leo leo* L.) and Siberian tigers (*Panthera tigris altaica,* Temminck) in Madrid Zoo [7]. Both white-tailed deer (*Odocoileus virginianus*) and Alaskan moose (*Alces alces, L.)* chose aromatic species of trees for rubbing Bowyer, et al. [8], and Barja, et al. [5] found that Iberian wolves (*Canis lupus signatus, Cabrera*) urinate mostly on trees with a thicker trunk.

Chemical marking structures play an influential role in communicating with sympatric mammals [1,9]. Moreover, foxes and lagomorphs are known to use clearings and landmarks for scent-marking behaviors [10,11]. Previous studies indicate that foxes defend their food resources from conspecific and heterospecific competitors using markings [10].

The Canidae comprise a principal group of predators [12], which typically shelter in dens dug into the ground, rock cavities, crevices, caves or hollows [13,14]. The red fox utilizes dens for birthing and rearing offspring ('breeding dens') and as resting sites outside the breeding periods ('non-breeding dens') [15]. Lactating females spend prolonged periods within the breeding den with their cubs during the initial few weeks of life [16].

The availability and quality of resources influence the size of the animal home range [17], such that, in canids, for example, a home range in a resource-rich area may be smaller than in a resource-poor area (e.g., 0.4 km^2 and >40 km^2 respectively [14]).

In northern Pakistan, Central Karakoram National Park (CKNP) is inhabited by major wildlife species of global importance such as snow leopard(*Panthera uncia*), some of which prey on or competitively displace red foxes [18,19]. Locally, the red fox is also a primary predator of small mammals (e.g, Royle's Pika or Indian Pika (*Ochotona roylei*) [20]. Major factors affecting red fox behavior and populations include roads and varying agricultural practice, whilst retaliatory killing for crop damage and prey depletion, local perception of the red fox as a pest species [21,22]. Although animals may use any of their diverse sensorial channels to obtain this information, most mammals are nocturnal and live in grassland. As a result, olfactory communication plays a principal role [3]. However, resource selection by red foxes in the region has not previously been subject to study and the effect of human disturbance on fox behavior and densities are unknown [23]. Here we hypothesize that, Do domestic dog can assistance to improve the detection of scats, red foxes choose specific substrates and aromatic or medicinal plants as signal posts in different habitats and also helping to the dispersal of seeds. Does fox use olfactory communication to interactions with opposite sexes?

Material and Methods

Study Location

This study was conducted in the Shigar Valley in the Karakorum range located along the north bank of the river Indus. It lies at 25° 25′32″ N latitude and 75° 42′59″E longitude and covers an area of 4373 sq. km with altitudinal amplitudes of 2, 260 to 8611 m above sea level including K2 (8611 m), Broad Peak (8047 m), Angel Peak (6858 m) and Skil Brum (7360 m) [24] see (Figure 1). We conducted this observational and non-invasive study according to the regulations for animal welfare and conservation under the Gilgit- Baltistan Wildlife Preservation Act 1975 and the North-east Forestry University Guidelines for the Use of Animals in Research.

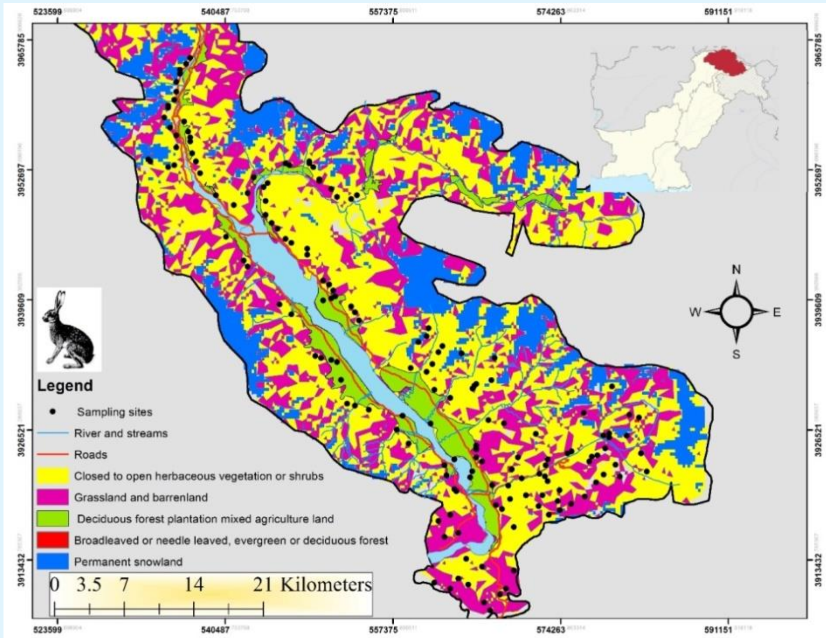

Figure 1: Sampling sites in Shigar Valley Karakorum range in both winter and summer.

Collection of Territory Marking Data

We used line transect and domestic dog (*Canis familiaris*) to detect feces throughout the 24h diel period, at night aided by torchlight [25,26]. We established a temporary 200 sample plot (10 m ×10 m) . We searched for fox faeces in each plot, and for every faecal sample detected we recorded associations with plant species following the technique described by de Miguel, et al. [27]. We considered an association to have occurred when feces were deposited adjacent to a plant (≤ 0.5 m) or on top of it. We also noted the classification and species of plant: wooden/herbaceous plants or shrubs, including aromatic herbaceous plants and shrubs within each plot (measured at 1 m above ground level). We additionally recorded carcasses, trails, livestock dung and rocks within ~2 - 5 m of the faeces where they occurred within the plot, and recorded the association as deposited on or near these substrates. The following plant species were considered: tree (woody) species (*Prunus armeniaca* , *Morus nigra, Salix alba* , *Elaeagnus angustifolia),* and herbaceous species (*Datura fastuosa, Mentha royleana Benth, Rheum webbianum Royle*) and shrubs (*Artemisia absinthium, Astragalus psilocentros Fisch, Capparis spinosa Linn, Hippophe rhamnoides, Ephedra gerardiana Wall, Rosa webbiana*). The seeds of food plants such as *Hippophe rhamnoids, Prunus armeniaca, Morus nigra, Elaeagnus angustifolia* and *Rosa webbiana* were found in fox feaces and were, therefore, also considered.

Data Analysis

Regarding feces as territory marks, we calculated the frequency of feaces associated with different substrates in different habitats, taking into consideration the usual distribution of fox feces within the plots. Our data did not follow a normal distribution and independence of the data was not assured as we did not perform genetic analyses to identify individual, and therefore the identity of the feces was unknown. Thus we used a Wilcoxon test [28]. And For each plot, we classified vegetation cover according to protocols described by Wang et al. [29], as well as the relative density, frequency, cover, and importance value index (IVI) of plant species, as described by Mahmood, et al. [30]. We also did not include 170, feaces in the final analysis due to bias. The Bonferroni Z-statistics were performed in SPSS 20.00 (SPSS Inc., and Chicago, Illinois, USA).

Results

Territory Marks

We identified in total of 467 fox scats by dog assistance and direct observation. In total, 44.4 % were associated with aromatic shrubs including *Artemisia absinthium* and *Capparis spinosa* in both barren areas and forest (Figure 2c). In the barren and open grassland, 18.4 % of the feces were associated with aromatic herbs, mostly *Mentha royleana Benth* and to a lesser extent *Datura fastuosa* (Figure 2b). Foxes favored shrub species over herbaceous species (Z = -2.497; P = 0.013). Of the woody plants, 35.1 % of fox feces were related to fruit trees in the forest, with the greatest frequency of scat linked to *Prunus armeniaca*, and lowest associated with *Elaeagnus angustifolia* (Figure 2a). Scat deposition was not significantly different between shrubs and trees (Z = -0.537; P = 0.591). Furthermore, fox feaces were significantly associated with livestock feaces and animal carcasses in the open grassland than barren areas (Z = -2.106; P = 0.02). The trend was observed where fox feaces were associated with rocks and animal trails in both the barren and open grassland habitats, but this was not statistically significant (Z = 0.161; P = 0.872).

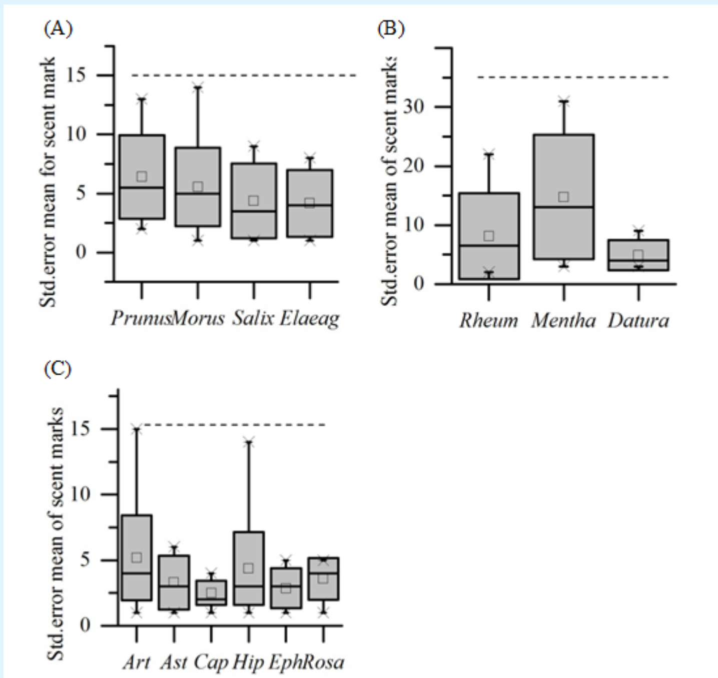

Figure 2: Mean (± SE) numbers of fox feces associated with different herbaceous and woody tree species in different habitat types as detected by a domestic dog. The dotted line indicates significant differences between groups. Feces were related to fruit trees in the forestland (A) associated with aromatic herbs plants in barren and open grassland. (B) associated with aromatic shrubs plants in barren and forest. (C) Represented shrubs species are *Artemisia absinthium. Astragalus psilocentros Fisch, Capparis spinosa Linn, Hippophe rhamnoides, Ephedra gerardiana Wall,* and *Rosa webbiana.*

Discussion

We found that foxes selected specific substrates or fruits trees and aromatic medicinal plants for territorial signal marking sites. Ecological factors such as temperature, substrate, and air currents, as well as experience levels, are known to influences the abilities of scat detection dogs [31]. The transmission of information by means of chemical signals is fundamental for many animals, playing a key function in the biological success of the individuals [32]. Foxes select plants as signal posts, for this reason, marking in places where they can be easily received by conspecifics.

As we predicted, the association of feaces with plants was notably higher in barren land than a forest, possibly because it was more detectable in the former. Polunin described foxes depositing scats on oaks and rockrose plants; hence they found these plants to have an attractive fragrance and sticky gums. Punjabi, et al. [33] found that wild fruit (*viz. Zizyphus mauritiana* and *Cássia* sp.) are significant components of Indian fox diet. Therefore, we expected wild fruit to positively influence the selection of signal posts at a smaller scale. In our results, woody plants were marked less than shrubs and herbaceous species, which contrasts with the findings of Barja, et al. [5] in Galizia, Spain. Carnivore scent profiles consist of sex-specific information on the reproductive state as well as individual identity cues and social organization [34].

Rocky substrates and animal trails were not preferred scent marking sites for red foxes, unlike in felids, especially solitary snow leopard, where scrape marking and scent marking and disproportionately focused on these areas [35]. The distribution of scats in different habitats may be used to infer dispersal distances, such as the fox movements reported by Walton, et al. [36], ranging from 132 to 1036 km. Furthermore, it is also possible that there is a competition of signal post resources with conspecifics (opposite sexes) or heterospecifics (prey species) [37].

Although animals may use any of their diverse sensorial channels to obtain this information, most mammals are nocturnal and live in grassland. As a result, olfactory communication plays a principal role [3]. The seeds of food plants such as *Hippophe rhamnoids, Prunus armeniaca, Morus nigra, Elaeagnus angustifolia* and *Rosa webbiana* were found in fox faeces and were, therefore, also considered. We also recorded that fox commonly ingests fleshy fruits and are thus likely to be important seed dispersers.

This study forms a baseline from which to explore predator-prey interactions and fox resource selection at different spatial scales. Foxes focus their activities near den sites throughout the breeding season and frequently visit dens at other times of the year, hence den location is an essential consideration in managing human-fox conflict and protecting natural prey species.

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