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Determining micro- and mesofaunal composition through the analysis of South American grey fox's feces in two different semiarid habitats

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Abstract. Information obtained from carnivorous´ scats when used for determining faunal composition in different habitats could be confusing if the carnivore does not depose its feces in the same habitat it is feeding or if the prey's home range is larger than the fox´s foraging habitat. In this study, the use of the presence and frequency of mammalian hair in the feces of the South American grey fox, *Pseudalopex griseus*, are proposed as indicators of the micro- and mesofaunal composition in two habitats (Creosote bush flats and Sierra) in a semidesert environment in central Argentina. These results are then compared to faunal composition determined by live trapping and tracks. The microfauna present was confirmed by using Sherman live traps, while the mesofauna was registered by tracks and direct observation over two consecutive years (2001-2002) and five sampling periods (three during dry seasons and two during wet seasons). For all sampling periods, feces of the South American grey fox collected in the Creosote bush flats contained hairs of species registered in that habitat, while scats collected in the Sierra habitat, contained hairs from mammals trapped or seen in the Sierras. This pattern holds at both sides of the narrowest portion (600 m) of a transition zone between these two habitats. Finally, we were able to unequivocally determined faunal composition though fox scats between two adjacent areas and we propose that fox scats are reliable indicators of fauna composition in a given habitat possibly related to low mean retention times when ingesting fruits.

[Keywords: carnivores, scat as indicators, *Pseudalopex griseus,* faunal composition]

Resumen. Determinación de la composición de micro- y mesofauna mediante el análisis de heces del zorro gris sudamericano en dos hábitats semiáridos: La información brindada por las heces de carnívoros en la determinación de la composición de la fauna en diferentes hábitats, podría ser confusa si el carnívoro no depone las heces en el mismo hábitat en el que se alimenta o por caso, si su área de acción es más amplia que la del hábitat en el que forrajea. En este estudio se propone el uso de la presencia y frecuencia de pelos de mamíferos en las heces del zorro gris sudamericano *Pseudalopex griseus,* como indicadores de la composición de micro- y mesofauna en dos hábitats (Jarillal y Sierra) en un ambiente semidesértico en la región central de Argentina. La presencia y frecuencia de pelos de mamíferos fue comparada con la composición de mamíferos determinada a campo. La microfauna de mamíferos fue confirmada usando trampas de captura viva tipo Sherman, mientras que la presencia de mesofauna lo fue mediante registro de rastros y observación directa. Los muestreos se llevaron a cabo durante dos años consecutivos (2001-2002) en cinco muestreos (tres durante la estación seca y dos durante la húmeda). En todos los períodos

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de muestreo las heces de zorro gris colectadas en el jarillal, contenían pelos de las especies de mamíferos capturadas o vistas en dicho hábitat, mientras que las heces colectadas en el hábitat de sierra contenían pelos de mamíferos observados o capturados en sierra. Este patrón se mantuvo inclusive a ambos lados de la porción más estrecha (600 m) de una zona de transición entre estos dos hábitat. Además, se pudo establecer inequívocamente la composición de la fauna utilizando heces de zorros, en dos ambientes adyacentes. Finalmente, proponemos que las heces de zorro son indicadores confiables de la composición de fauna en un hábitat dado, posiblemente relacionado con bajos tiempos medios de retención cuando los zorros ingieren también frutos.

[Palabras clave: carnívoros, heces como indicadores, *Pseudalopex griseus*, composición de fauna]

INTRODUCTION

Results from owl pellets and mammal feces analyses have been widely used as indicators of faunal composition (IFC) in particular habitats (Jaksic et al. 1999; Rifai et al. 2000; Monserrat et al. 2005). These indicators are of special importance in those environments where human artifacts, such as trap grids, exhibit a low rate of success (Jaksic et al. 1999). Given that faunal composition varies with time of the year, precipitation or patch size, it is important to know the accuracy and precision of the estimation of faunal composition within a small to medium size spatial scale (Degen 1997; Pia et al. 2003; Zuercher et al. 2005; Correa & Roa 2005; Trejo et al. 2005). However, this may require knowing in detail the exact faunal composition through other methods all of which have particular and different assumptions. This is why the discussion regarding the use of IFC's should take into account the consistency of the relationship between the observed faunal composition (measured by different trapping or observational methods) and the one inferred from the use of scats. A main problem in using fox scats as IFC is that fox homerange can be larger than an habitat type and then the information on faunal composition from one habitat is confounded with the faunal composition of the other habitat.

Prey composition of fox scats is made of small and medium size vertebrate remains (i.e., bones, teeth, scales, feathers, and especially hairs), which can be rather easily determined and classified (González del Solar et al. 1997; Jaksic et al. 1999). However, the majority of studies involving fox fecal analysis, have been used to establish both the diet of foxes and the potential impact of these canids on domestic cattle (Pia et al. 2003; González del Solar & Rau 2004), the trophic ecology of foxes, seasonal variation in diet or variability in diet at different spatial scales or habitat types (Jaksic et al. 1999; García & Kittlein 2005; Farías & Kittlein 2007). In the first case there are indicators of prey availability, or their presence or absence in those habitat, while in the second there is not.

In other parts of the world, fox diet has been used to answer questions regarding variation among habitats in faunal composition or resource use. These studies however, have not been followed over time. (Kapel 1999; Fredrik & Angerbjörn 2000; Dell'Arte & Leonardo 2005).

This is the first study for Argentina reporting a highly consistent pattern between the faunal composition determined by trapping and observation in two adjacent habitats of the northwestern region of San Luis province in Argentina and the faunal composition of each habitat as indicated by the analysis of the South American grey fox (*Pseudalopex griseus*) scats.

METHODS

Study area

Sierra de las Quijadas National Park (32°47′ S and 67°10′ W at 800 m altitude) is located 116 km north from San Luis City, in Central Argentina (Figure 1). The area is an ecotone between the Monte phytogeographical province (dominated by xerophytic, resinous and thorny shrubs) and the Chaco province (dominated by an open hardwood forests) (Cabrera 1976). This region is one of the driest areas in San Luis province. Seasonal precipitation is

266 mm and 86 mm during the wet (October to March) and dry (April to September) seasons, respectively (National Park Administration, unpublished data.) Within the limits of the Park, two different habitats are distinguishable: the Creosote bush flats and the Sierra. The vegetation of the Creosote bush flat is characterized by the presence of *Larrea cuneifolia*, *Opuntia* sp, *Tephrocactus* spp and isolated individuals of *Aspidosperma quebracho-blanco*, and groups of *Prosopis torquata* at the edges of this habitat. The Sierra habitat is dominated by *Larrea divaricata*, *Bromelia* spp. and small forests of *Prosopis torquata* and *P. flexuosa*. Between these two habitats there is a NW–SE straight transition line of a minimum width of 600 m, where species from both habitats are present (Haene & Gil 1991) (Figure 1). The maximum distance between the eastern border of the Creosote bush flats and the western border of the Sierras in the study area is 7 km. The mean distance between both habitats is 3.5 km. (Figure 1). The Sierra and Creosote bush habitats area comprised 8.7 km^2 and 6.1 km^2, respectively. The dominant soil in the Creosote Bush Flat is an argillaceous aridisol, while the Sierra is composed of Quaternary sediments and sedimentary rock outcrops of consolidated gravel and sand of neotectonic origin (Rivarola & Spalletti 2006).

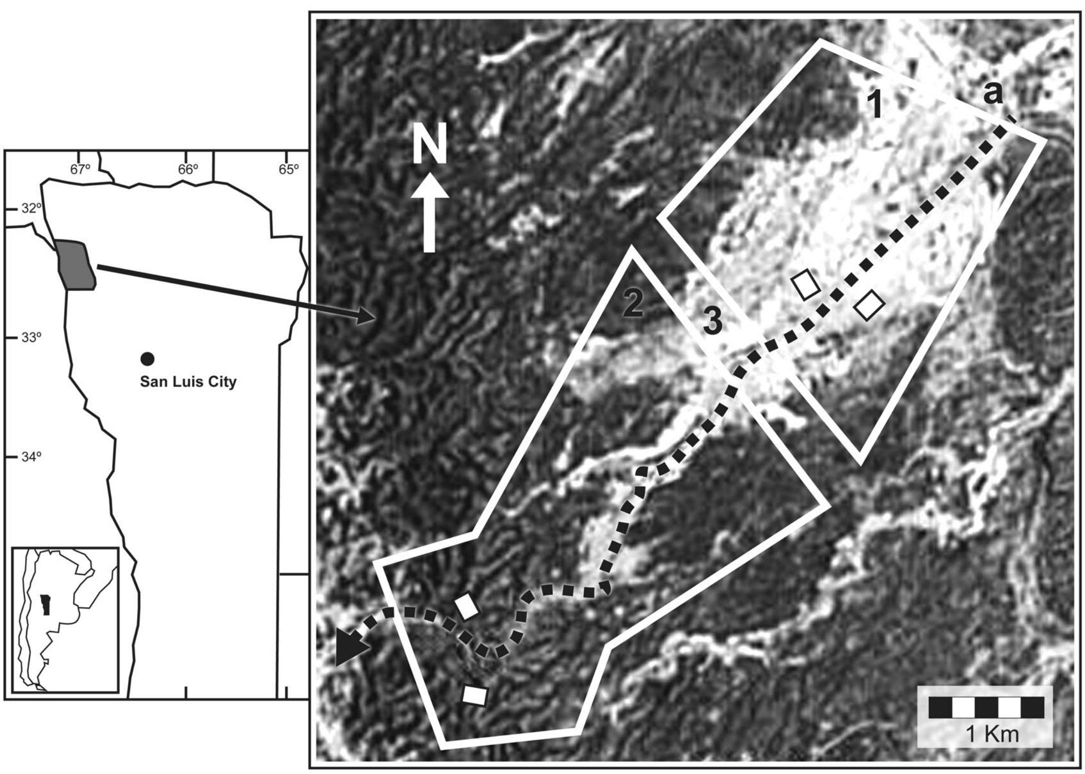

Figure 1. Habitat location, sampling and trapping zone in Sierras de las Quijadas National Park, San Luis, Argentina. 1: Creosote bush habitat; 2: Sierra habitat; 3: transition zone. Small white rectangles: Sherman live-trap grids. White lines delimit scat collection areas. Dot line: internal road.

Figura 1. Ubicación del hábitat, las zonas de muestreo y trampeo en el Parque Nacional Sierra de las Quijadas, San Luis, Argentina. 1: hábitat de Jarillal; 2: hábitat de Sierra; 3: zona de transición. Rectángulos blancos pequeños: grillas con trampas de captura viva tipo Sherman. Líneas blancas limitan la zona de recolección de heces. Línea punteada: camino interno.

Scat sampling and mammal trapping procedures and observations

Rodent and scat samplings and mammal sights were carried out in both habitats during the same field trip. Two dry season samplings were undertaken in 2001 and one in 2002. During the wet season, one was done in 2001 and the other in 2002. Fresh feces of South American grey foxes were intensively searched for in the two habitats and in the transition zone, by 8 persons during 5 hours each, over 4 days. The sampling effort totaled 160 hours per sampling period, and a total sampled area of 14.8 km^2.

Hairs in feces were used for the identification of prey, at species level when possible. Once in the laboratory, scats were oven dried and prepared for hair identification following Chehébar & Martín (1989). Briefly, each scat was soaked in hot water to disaggregate it, then washed with 70% alcohol and the whole homogenous sample was put into a 2.5 cm diameter Petri dish. A quarter of the sample was used to search for mammalian hairs. Guardian hairs were mounted on slides, using transparent nail enamel in order to obtain hair scale prints. Scale and medullar patterns were used for identification by comparing them with an ad-hoc collection of hairs of micro- and meso mammals from the area (Chehébar & Martín 1989; Fernández & Rossi 1998).

Small mammals were sampled using Sherman live traps arranged in four grids of five columns by 10 rows each, with individual traps placed at a distance of 20 m from each other. Traps were baited with rolled oats and operated during three consecutive nights. Mammals were identified at genus and species level, when possible. Mesofauna presence was registered by tracks and direct observation during fox scat samplings. Relative abundance was calculated as the number of animal per 100 trap nights. Differences in the number of feces collected, relative abundance of small mammals between seasons and differences between habitats in the number of scats collected were tested using a two-sample t-test. A value of $P \leq 0.05$ was considered significant.

Results

A total of 71 scats were collected during five field trips (Figure 2). There were no statistical differences on either the number of scats collected between the dry and wet season (t_8=1.37, P=0.21) nor between habitats (t_5=2.17, P=0.17). No scats were found inside the transition zone.

Species richness of mammals was different in the two habitats. While nine species were found in the Sierra, only four were detected in the Creosote bush flats. Only two out of a total of 11 species found, *Dolichotis patagonum* and *Calomys musculinus*, were present in both habitats (Table 1). Small mammal abundance, as measured with Sherman-live traps, was not

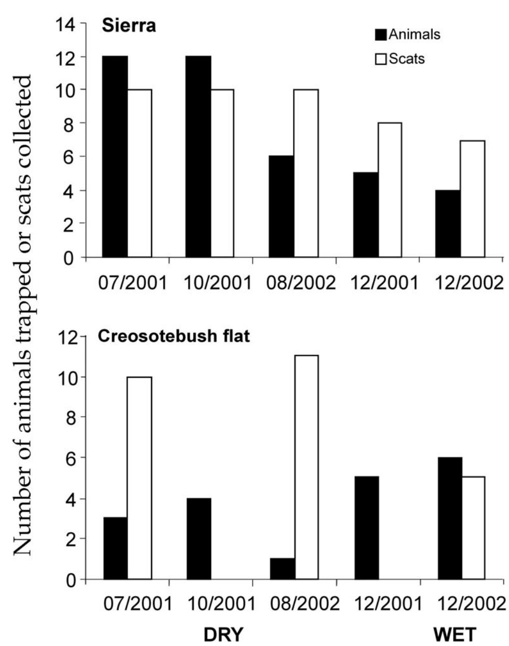

Figure 2. Total number of small mammals trapped and fox´s scats collected in the Creosotebush flat and Sierra habitats, during five samplng periods. Three during the dry season and two during the wet season.

Figura 2. Número total de pequeños mamíferos capturados y heces de zorros recolectadas en hábitats de Jarillal y de Sierra, durante cinco períodos de muestreo. Tres durante la estación seca y dos en la estación húmeda.

Table 1. Micro and mesofauna live-trapped and sought versus number of scats containing hairs of identified species, in two habitats in the Sierra de las Quijadas National Park, San Luis, Argerntina.

Tabla 1. Micro y mesofauna capturada o vista versus el número de heces que contienen pelos de las especies identificadas en dos hábitats en el Parque Nacional Sierra de las Quijadas, San Luis, Argentina.

	Traps-sight / Scats	
Mammals	Sierra	Creosote bush flats
Didelphidae: *Tylamys pusilla*	2 / 0	0 / 0
Didelphidae: *Didelphys albiventris*	Yes / 4	No / 0
Cricetidae: *Akodon sp.*	4 / 1	0 / 0
Cricetidae: *Phyllotis xanthopygus*	11 / 0	0 / 0
Cricetidae: *Graomys griseo avus*	19 / 3	0 / 0
Cricetidae: *Calomys musculinus*	2 / 5	1 / 1
Cricetidae: *Andalgolomys olroigi*	0 / 0	17 / 1
Cricetidae: *Eligmodontia typus*	0 / 0	1 / 0
Cavidae: *Dolichotis patagonum*	Yes / 3	Yes / 2
Cavidae: *Galea musteloides*	Yes / 1	0 / 0
Unidentified rodent 1	1 / 1	0 / 0
Total in traps / Total scats	39 / 18	19 / 4
Trap effort (N° traps/night)	1500	1500
Mammals / 100 trap-night	2.53	1.27

statistically different between seasons (t_8=0.91, *P*=0.4). *Phyllotis xantophygus*, *Thylamys pusilla* and *Eligmodontia typus* were the only three species that did not appeared in any of the feces analyzed.

DISCUSSION

Fox's feces collected in Creosote bush flats always contained hairs of the species trapped or seen at this location, while feces collected in the Sierra, always contained hairs from mammals trapped or seen in this habitat. This pattern holds even at the border line of the transition zone (Figure 1, Table 1).

Not all species of small mammals present (trapped or seen) in the studied habitats were found in fox scats. Two rodents (*Phyllotis xantophygus, Eligmodontia typus*) and the small marsupial *Tylamys pusilla*, all of which were trapped in the sampled area, were not detected by fox scat analyses. Absence in the feces of these species may be due to different factors or circumstances. The absence of remains of *P. xantophygus*, may be explained by the fact that it was trapped only on the slopes of sedimentary rock outcrops, and no fox scats were found in the Sierra on this soil type. The scats within the grid of all other microhabitats, contained all species except *P. xantophygus.* This means that foxes do not prey on this species and coincidentally do not defecate on the slopes of sedimentary outcrops.

In turn, the absence of *E. typus* hairs in our samples is likely to be related to the remarkably low abundance of the former species in the study area. Indeed, our total capture effort of 3000 night/traps yielded only one individual of this murid. Reports on the diet of the South American grey fox based on scat analyses carried out at nearby areas of Bosque Telteca Reserve (32º23'27" S; 68º1'30" W) and at the Man and the Biosphere (MAB) Reserve of Ñacuñán (30º03´ S, 67º58´ W) included *E. typus* as one of the most important preys (González del Solar et al. 1997). Finally, failure to detect hairs of *T. pusilla* in fox feces might be associated to the fact that this marsupial is arboreal (Rau et al. 1995) so using grey fox scats as indicators is obviously only valid for terrestrial micromammals.

¿What conditions may be shaping these findings? Key factors in understanding our results could be, on the one hand, the animal physiology. For example, the culpeo fox (*Pseudalopex culpaeus)* has a mean retention time (MRT) of 28 h when feeding only on a meat diet, while MRT changes to 18.8 h when fed with a mixed diet of fruit and meat, and to 12 h when fed only on fruits (Silva et al. 2005). Varela and Bucher (2006) reported that passage time of seeds of four native fleshy-fruit species (*Ziziphus mistol, Acacia aroma, Celtis tala*, and *Syagrus romanzoffiana*) through the guts of the Pampas fox (*Pseudalopex gymnocercus*) and the crab-eating fox (*Cerdocyon thous*) averaged 6.8 h and 7.7 h, respectively. On the other hand and, in relation to the ingestion of *Prosopis torquata* pods by foxes, we have observed that up to 80% of the scats of the South American grey fox in Sierra de las Quijadas, are composed of *P. torquata* pods. Considering that *Pseudalopex griseus* and *P. culpaeus* are species with very similar feeding habits (González del Solar & Rau 2004), it is reasonable to suggest that the MRT of the South American grey fox might be somewhere between that corresponding to a mixed diet and that of an only fruit diet, reported for *P. culpaeus* (Silva et al. 2005).

We suggest three possible explanations for the consistency in the correspondence between scat composition (as indicator of faunal composition) and faunal composition as determined in the field, in these habitats: (a) mean retention time for *P. griseus* is extremely low, ensuring that scats deposition takes place in the habitat the fox is foraging in; (b) *P. griseus* moves and forages more intensively and for longer periods of time, within habitats than between habitats. The foraging behavior of foxes within the limits of Parque Nacional Torres del Paine (Chile) has been described as "slow walking with abrupt irregular turns through the low (<500 mm) vegetation" (Johnson & Frankling 1994) and (c) the home range of *P. griseus* in this environment is narrower than has been reported.

The use of fecal analysis for determining faunal composition is comparable to that of owl pellets (Rifai et al. 2000; Monserrat et al. 2005; Trejo et al. 2005) in the sense that scats are easy to locate and species determination by hair or bone analysis is not time-consuming. Moreover, the low vagility of foxes compared to owls may help to obtain a better (because of its consistency and faunal content) pattern of fauna composition.

In this study, we report a straight and constant relationship between faunal composition determined through scat analysis and fauna location and composition determined by live-trapping methods and observations, during five field trips and two years. We were able to unequivocally determine faunal composition through fox scats in two adjacent areas and even, at a small space scale (microhabitat) on the slopes of sedimentary rock outcrops in the Sierra habitat. The home range of the South American grey fox varies from 2 to 3 km^2 (Gonzalez del Solar & Rau 2004). This data implies that a fox would move approximately 1600 m (calculated from an ideal circular home range, with a diameter of 1600 to 2000 m) and a maximum of between 2000 and 3000 m if it moves only in an 1 m wide straight line. Given that (a) the minimum distance between habitats (Creosote bush flats and Sierras) is 600 m, (b) scats were found at both sides of the limit between habitats, and (c) the mean distance between both habitats is 3.5 km, we confirm that mammalian hair in foxes feces is a useful indicator of terrestrial faunal composition and distribution in desert environments, to be used as complement to live traps and pellet sampling.

Finally, we propose that that fox scats are consistent indicators of fauna compositions in a given habitat when ingesting fruits (pods or seeds), giving the impact fruits have in fox´s transit time. This is a scenario completely unexplored in our country, even tough there is some literature reporting ingestion of fruits by the small grey foxes (González del Solar & Rau 1996, Campos y Ojeda, 1997 and Nuñez & Bozzolo 2006). We aim to determine in the near future our own estimations of MRT in foxes eating *P. torquata* pods and to have better estimations of foxes' movement within and between habitats.

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