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Taphonomic Analysis of *Pseudalopex griseus* (Gray, 1837) Scat Assemblages and their Archaeological Implications

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Grey fox (*Pseudalopex griseus*) scats deposited in the immediate vicinity of guanaco (*Lama guanicoe*) carcasses were analyzed to evaluate this carnivore´s transport of bones. Samples were from the arid, semi-desert Río Negro Province, Argentina, where the annual mean temperature (15ºC) varies widely with the season. Rates of breakage, the presence of tooth marks and digestion traces on bones from scats were analyzed to categorize the taphonomic signature of the small grey fox. The values of the modification variables used in the categorization indicate that the grey fox (*Pseudalopex griseus*) may be considered a Category 5 predator.

Keywords: TAPHONOMY, DIGESTION TRACES, GREY FOX, MICROMAMMALS, PATAGONIC STEPPE.

Introduction

In archaeological sites from the Pampean and Patagonian regions, the record of micromammals (especially rodents) and carnivores is very common. A great part of these remains do not present evidences of human modification (Borrero *et al*., 2005; Martinez, 1999; Politis, 1984; Madrid & Salemme, 1991; Gutiérrez, 2004; Bonomo & Massigoge, 2004). In this context, the development of taphonomic studies is very

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important to separate those bones associated with human activity from those that were deposited by predators. Consequently, in the past few years, actualistic taphonomic studies have been carried out which contribute to the evaluation, the modification and transport of bone assemblages by carnivores from the south of South America (Borrero, 1990; Borrero & Martin, 1996; Borrero *et al*., 2005; Kaufman & Messineo, 2002; Martin & Borrero, 1997; Mondini, 1995, 2000; Nasti, 1996; Martin, 1998).

This work analyzes the taphonomy of prey bones from small grey fox scats, deposited in an open air situation. Grey fox scats deposited on, or near, guanaco (*Lama guanicoe*) carcasses were analyzed and a measure of the bone and animal species transport by the fox was developed, as a tool to help determine fox contributions to archaeological sites. In the great majority of cases, evidence of fox activity is not clear, and a discussion of the integrity of the faunal record is required.

Objectives of study

1.Categorize the small grey fox sample obtained, according to the methodology of Andrews (1990). Bones from scats were analyzed for breakage patterns, presence of tooth marks and digestion traces.

2. Determine fox scat influence on the integrity of the bone record from open-air sites.

Over the last 20 years, taphonomic studies have used modern methods to clarify the hunter and scavenger behaviour of some predators (Shipman & Walker, 1980; Andrews & Evans, 1983; Sutcliffe, 1970). These studies emphasized the analysis of predator modifications on bones and their ability to transport remains of other species to archaeological and palaeontological sites.

In one of these works, Andrews (1990), evaluates the various modifications made by some predators, specifically from the Northern Hemisphere. Quantitative and qualitative variables were used to classify, in five categories, modifications due to carnivores, and nocturnal and diurnal birds of prey.

These categories, designed for Northern Hemisphere predators, can be applied to those from South America. This methodology has recently been applied to predators from the Pampean region (Gómez, 2000).

Studies by researchers show that carnivore ingestion (including chewing and gastric juices), seriously damages skeletal parts of prey, leaving a large number of fractures and intense digestion traces (Andrews, 1990). It is expected that fox digestion, like that of other carnivores, seriously damages ingested bones. However, recent studies in South African small carnivores suggest that 100% of molars and incisors appear with evidence of digestion traces in a moderate degree (Matthews, 2006) According to the low rates of guanaco-carcass bone damage recorded, we postulate a small percentage of bones ingested from medium and large-sized species.

Based on the scavengered carcasses recorded, scats should contain soft tissue such as skin, hair and cartilage. We hypothesize that on carcasses of dead animals, even for long periods such as for several months, there will remain some skin and soft tissues that are attractive to scavenger species such as foxes. Therefore, fox activity, which could possibly occur simultaneously and alternating with human on-site activity, could decrease the integrity of the archaeological record.

Area of Study

The samples studied were from the "Cinco Chañares" farm, San Antonio Department, Río Negro Province (40º 36' LS y 65º 25' LW) (Figure 1), where guanaco carcasses, recovered to create a taphonomic reference collection. Rainfall is scarce (average 250 mm; Lizuain, 1983) in this arid, semi-desert region; the annual mean temperature (15ºC) varies widely according to the season.

The area is in the Monte fitogeographic province (Cabrera, 1953). Rich in burrowing mammals (generally the same species in the Northern Monte and Patagonic Steppe), the fauna most characteristic of the area are: mara (patagonic hare) (*Dolichotis patagonica*); small grey fox (*Pseudalopex griseus*); puma (*Puma concolor*); guanaco (*Lama guanicoe*) and ñandú (*Rhea americana*).

Carcasses were recorded in an area of plateaux and erosion terraces covered by an extensive layer of rounded, glacifluvial stones. Wetlands form seasonally in the lowlands in the area.

Carcasses of 158 guanaco were recorded. They had died after becoming entangled in nets, or had been killed by pumas and poachers. The scats analyzed came from the guanacos numbered G27-G29-G47-G51-G55-G52-G58-G63 (Table 1). The largest number of fox scats (n=29) were recorded in the vicinity of carcass G47. In all cases, scats were found in the immediate vicinity of carcasses.

Scats were assigned to fox on the basis of morphological characteristics, and, in some cases, by the presence of fox tracks near the carcass. The carcasses found in spatial connection to scats probably acted as foxes feeding places.

Grey Fox Ethology

In the Patagonian Northeast, one of the main carnivores and scavengers modifying carcasses is the grey fox, or chilla *(Pseudalopex griseus)*. Modifications on carcasses can also result from the behavior of introduced species, such as dog (*Canis familiaris*) and wild boar (*Sus scrofa*), and other native species, such as armadillo (*Chaetophractus villosus*) and carrion birds, such as the black-headed jote (*Corapips atratus*) or red-headed jote (*Cathartes aura*).

Smaller than the pampean fox, the grey fox weighs approximately 4.4 kg, its body length measures 0.75 m and its tail 0.33 m. Inhabiting plains, pampas, deserts and low mountains (up until 4,000 m), its omnivorous diet includes small mammals, reptiles, birds, invertebrates and fruit (Cabrera & Yepes 1960; Novaro, 1997).

Dens are created mostly in rock crevasses, under shrubs, in burrows abandoned by other species, or at the foot of tree trunks. The grey fox is principally nocturnal, but can be active during daylight (Nowak & Paradiso, 1983).

Methodology and materials

The majority of scats recovered were dehydrated. Fresh scats were collected in July 2003, but January 2004 field work produced no fresh scats, and no evidence of fox scavenging on carcases. Almost all scats were found in the immediate vicinity of guanaco carcases. Scat size is diverse; some

Table 1. Scats analysed from the spots where guanaco carcasses were found.

Carcass	Nº Scats recovered	Material	NISP
G27	1	Rodent hair	0
G29	1	Insects – hair – organic material – bones	21
G47	29	*Lama guanicoe* hair and leather – stones – rodent hair – bones	97
G52-53-54	2	Rodent hair – insects – dermestid – bones	28
G55	1	Bones – cartilage – insects – feathers	18
G56	1	Insects - dermestid – rodent hair – organic material - turtle bony plate – bones	57
G57	19	Rodent hair – bones– seeds	178
G58	1	Rodent hair - dermestid – insects – bones	4
G63	2	Hair – seeds – bones	16
G71	2	Feathers – rodent hair –leaves –organic material - bones	53
Total	59		472

Table 2. Relative abundance of skeletal parts obtained from fox scats.

	MNE	%
Maxilla	21	95,5
Mandible	14	63,6
Scapula	8	36,4
Humerus	4	18,2
Radius	3	13,6
Ulna	4	18,2
Pelvis	6	27,3
Femur	13	59,1
Tibia	5	22,7
Fibula	1	4,5
Vertebrae	52	13,1
Incisor	24	54,5
Molar	54	40,9
Calcaneus	4	18,2
Astragalus	2	9,1
Rib	5	1,9
Metapodial	14	6,4
Phalanx	30	4,9
Total	264	

Table 3. Results of indexes (see text for explanation).

Considered variables	Values
MNI	11
pc/c	82,9 %
f+h/md+mx	48,6 %
t+r/f+h	47,1 %
Isolated molars	75 %
Isolated incisors	96 %
Relative Abundance	25,8 %

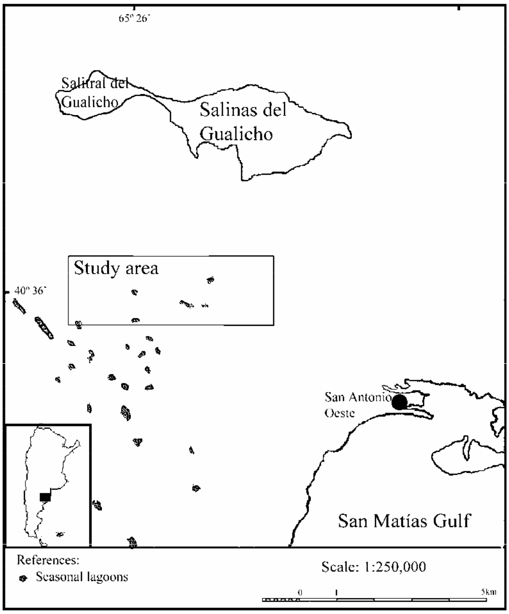

Figure 1. Map showing the location of the area were the fox scats were collected.

Figure 2. Processing scats samples.

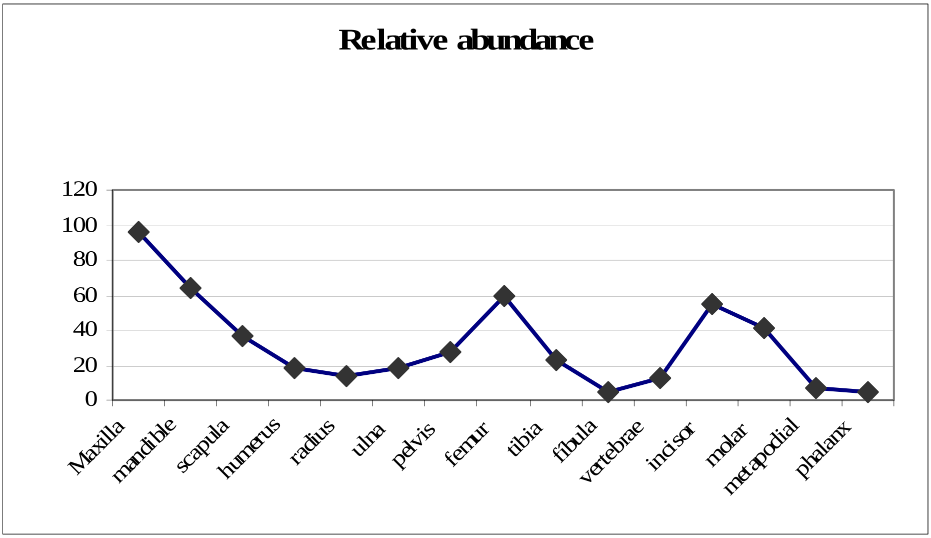

Figure 3. Curve of relative abundances of skeletal parts.

scats were complete, others were broken into fragments. In the latter case they were considered as part of assemblages.

Each sample or assemblage of the entire sample (N=59) was dipped in water (Stallimbrass, 1990), allowed to dry, then screened (2 mm mesh) to separate bones, insects, hair and seeds. The content was then recorded and stored for future analysis (Figure 2).

Second-stage quantification of the material found, anatomical determination and taphonomic analysis was carried out with the aid of a binocular glass from INCUAPA, Facultad de Ciencias Sociales, Olavarría, Universidad Nacional de Centro de la Provincia de Buenos Aires, Argentina. In the next stage, Scanning Electron Microscope (SEM) images were obtained from a sample of micromammal elements from various areas in the site. Images were obtained from the Museo Nacional de Ciencias Naturales (Madrid, Spain) scanning electronic microscope with: FEI Quanta 200 environmental chamber; secondary electron detection and retro-dispersion for low, high and environmental vacuum; Oxford Instruments Analytical – INCA integrated analysis system, with two simultaneous or alternate EDS (energy dispersal) or WDS (wave dispersal) X-ray detecting systems.

The variables used in this work, the same as those proposed by Andrews (1990) and Fernández Jalvo (1992), are:

A*- Anatomical representation.*

B*- Postcranial and cranial skeletal part representation variability, using two fractions:*

$$\frac{Pc}{c} = \frac{(\text{femur} + \text{tibia} + \text{humerus} + \text{radius} + \text{ulna}) \times 16}{(\text{mandible} + \text{maxilla} + \text{molar}) \times 10}$$

and

$$\text{f} + \frac{\text{h}}{\text{md}} + \text{mx} = \left(\frac{\text{femur} + \text{humerus}}{\text{mandible} + \text{maxilla}} \right)$$

where pc: postcranial; c: cranial; f: femur; h: humerus; md: mandible; mx: maxilla.

C*- Distal part loses of apendicular skeletal parts:*

$$\text{t} + \frac{\text{r}}{\text{f}} + \text{h} = \left(\frac{\text{tibia} + \text{radius}}{\text{femur} + \text{humerus}} \right)$$

where t: tibia; r: radius.

D- Quantification and analysis of fractures.

E- Comparing isolated molars and incisors with tooth loss from the mandibles and maxillae.

F- Digestion traces (light, moderate, strong and extreme) on postcranial elements, incisors and molars.

G- Weathering and carnivore ingestion marks (pits – punctures – scratches).

Results

Samples consist of a majority of small mammals and other small to medium-sized animals, unlike assemblages transported to dens (Mondini, 2000) and those from scavenged carcasses. The grey foxes, due their territorial behavior, introduce micromammal species which are not representative of the area where the *Lama guanicoe* carcases are scavenged. Both types of data must be considered to obtain a representative view of these canids and the taphonomic processes involved.

The number of scats in or around each carcass varied from 1 to 29. Small rodent bones, cranial elements and feathers were identified from the scats. In carcass 56, small bony turtle plates were found, as well as bone fragments that can be assigned to *Lama guanicoe*, and also hair and cartilage. A great number of insects and seeds were also recorded. The NISP (number of identified specimens) from the number of scats recorded by carcass varied from 0 to 178, with an average of 47.2 (see Table 1).

Table 2 and Figure 3 display the curve of relative abundances of skeletal parts obtained from fox scats. The curve is not saw-toothed, as is usual in the case of nocturnal birds of prey (*Tyto alba*, *Asio flammeus*, *Bubo virginianus*). The curve in Figure 3 is less jagged, but with peaks in abundance in the maxilla, femur and incisor, also indicates that cranial element relative abundance is similar than postcranial. The value of Pc/c index is near to equilibrium between cranial and postcranial elements (82.9%), with a slow majority of cranial elements. This majority is notorious with the f+h/md+mx index value, which reaches only 48.6%, an indication of greater survival of cranial elements. The t+r/f+h index indicates good survival of appendicular elements, reaching 47.1%. Rates of isolated incisors and molars reflect a small loss of molars and incisors and possible destruction of maxillae and mandibles (Table 3).

A large percentage of broken appendicular elements were recorded, but some humeri, tibiae and ulnae are complete; no complete femora were found. The majority of broken elements correspond to proximal ends, both isolated and associated with shaft fragments. No isolated shafts were found in scats (Table 4).

The percentage of elements with digestion traces is high; 100% of diagnostic cranial elements, such as isolated and *in situ* molars and incisors, show evidence of digestion; there is also a similar digestion evidence on all the humeri. On the proximal end of the femora there is a high percentage of digestion alteration (53.8%) (Table 5 and Figure 4).

All the diagnostic skeletal elements show a light degree of digestion, which reaches 72.7% in the case of *in situ* incisors (Figure 6). A moderate degree of digestion is recorded on all diagnostic skeletal parts; on isolated incisors it is 53.8%.

A strong degree is recorded on both isolated incisors, and *in situ* and isolated molars. *In situ* molar elements are seen to have undergone the highest percentage of strong digestion alteration (36.3%). Only *in situ* molars show extreme digestion (9.1%) (Figure 6).

No complete cranium was recorded but only 4 cranial fragments (Table 6).

Table 4. Percentages of broken elements.

	Femur	%	Humerus	%	Tibia	%	Ulna	%
Complete	-	-	1	25	1	20	1	25
Proximal End	7	53,8	-	-	-	-	1	25
Distal End	-	-	-	-	-	-	-	-
Proximal End and half shaft	4	30,8	1	25	2	40	2	50
Distal End and half shaft	-	-	3	75	1	20	-	-
Shaft	-	-	-	-	-	-	-	-

Figure 4. Proximal end of femur with digestion traces.

About 38% of the maxilla has a zygomatic arch, and 61% a palate. A high percentage of maxilla incisors (76.1%) and molars (80.9%) are missing.

No complete mandible was found; the ascending ramus of 28.5% of mandibles was broken, while the lower rim of 57.1% of mandibles was broken, 28.5% corresponds to diastema. Molars were missing in 50 % of mandibles and some 64.2 % of incisors were also missing.

Broken dental material found in the sample is not abundant; most remarkable is the absence of broken *in situ* incisors. Only 3 % of *in situ* molars were broken, 14.2% of isolated molars were broken, and 15.3% of isolated incisors were broken. Some 7.4% of all molars were broken, and broken incisors composed 8.3 % of the incisor sample.

Discussion

This *Pseudalopex griseus* sample is sufficiently diagnostic to enable the evaluation of grey fox modifications, such as fractures and digestion traces (Figure 7). Results obtained coincide with those presented by Andrews (1990) for small Northern Hemisphere carnivores. Values of category variables indicate that grey fox (*Pseudalopex griseus*) modifications should be considered Category 5, even though some values fall within Category 4 and others within 1, 2 and 3 (Figure 8).

No skeletal parts of predators were found on site, but evidence of their activity was found. Records of 3 or 5 rodent species were found, but there is no evidence that they lived on the site. These observations would indicate that some zoo-archaeological interpretations based on species found on site can be subject to error caused by faunal transport by predators or scavengers.

This method can be a useful tool for zoological interpretation (especially of taphonomic history) of archaeological or palaeontological sites. Using this method, some species appearing in a site may be identified as intrusive, thus avoiding their

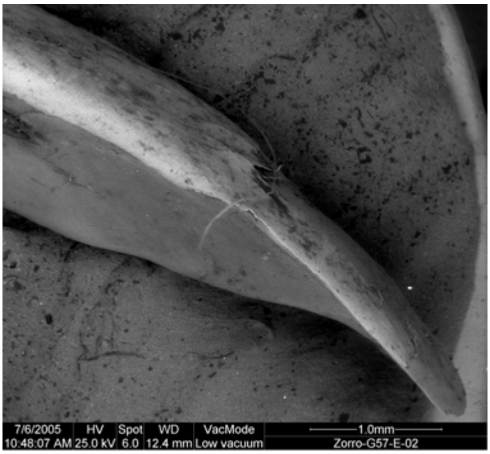

Figure 5. Isolated incisor with a moderate degree of digestion.

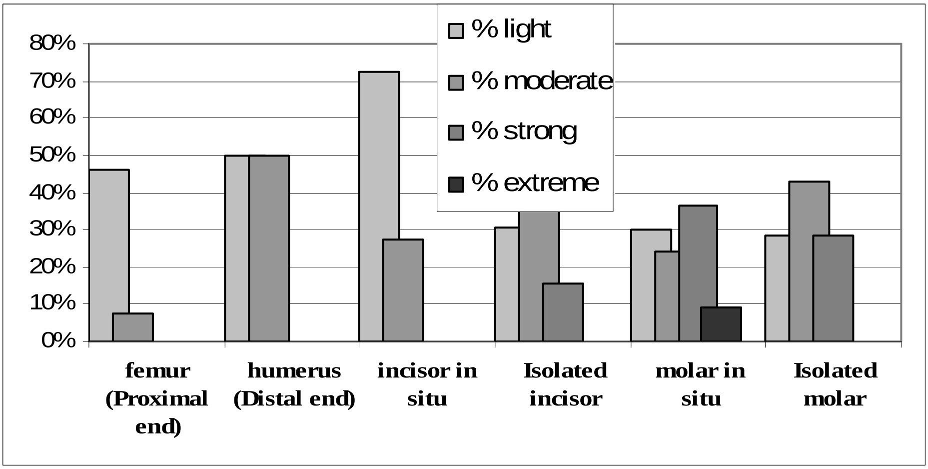

Figure 6. Frequencies of digestion degrees recorded in each skeletal part.

Figure 7. Rodent vertebrae with digestion traces and fox tooth marks.

Figure 8. Results of grey fox categorization.

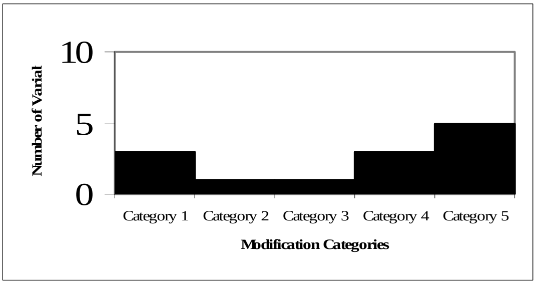

Table 5. Percentages of cranial and postcranial elements with categories of digestion traces.

	MNE	Digested	%	Light	%	Moderate	%	Strong	%	Extreme	%
Proximal end femur	13	7	53,8	6	46,2	1	7,7	-	-	-	-
Distal end humerus	4	4	100	2	50	2	50	-	-	-	-
Incisor *in situ*	11	11	100	8	72,7	3	27,3	-	-	-	-
Isolated incisor	13	13	100	4	30,8	7	53,8	2	15,3	-	-
Molar *in situ*	33	33	100	10	30,3	8	24,2	12	36,3	3	9,1
Isolated Molar	21	21	100	6	28,6	9	42,9	6	28,5	-	-

Table 6. Cranial elements recorded from fox scats.

	MNE	%
Broken cranial	4	
Complete	-	-
Maxilla with zygomatic	8	38,1
Palate	13	61,9
Maxilla lost molars	51	80,9
Maxilla lost incisors	16	76,1
Broken Mandible	1	
Complete	-	-
Ramus ascendant broken	4	28,5
Inferior border broken	8	57,1
Mandible molars lost	21	50
Mandible incisors lost	9	64,2
Diastema	4	28,5
Broken molars *in situ*	1	3
Broken isolated molars	3	14,2
Broken incisors *in situ*	-	-
Broken isolated incisors	2	15,3
Total broken molars	4	7,4
Total broken incisors	2	8,3

erroneous attribution as a human resource (in the case of archaeological sites) or as being diagnostic of environmental conditions (in archaeological and palaeontological sites). Through significant variable analyses (Andrews, 1990; Fernández Jalvo, 1992), digestion traces can be documented, and from them, predated species identified. In addition, the trophic chains that operated on site and post-depositional alteration of assemblages can be elucidated, providing important information for palaeo-environmental interpretation.

In fox scats, some bone fragments attributable to *Lama guanicoe* were found, although they are not diagnostic. Other identifiable fragments of small vertebrates and insects, and *Lama guanicoe* skin and hair which were found in the scats, are elements rarely preserved in fossil sites.

This study adds more information to the discussion of the possible biotic relations (commensalism, competence) that could exist between humans and other species in a shared environment, viewing a region not only as a place where human groups use various resources, but also as a complex network of ecological relationships.

The results presented here contribute to the analysis of micro and mesomammals from Pampean and Patagonian open air archaeological sites. These results can be considered as initial parameters to evaluate potential fox modification of bones deposited at open-air archaeological sites.

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