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Taphonomic analysis of rodent bone accumulations produced by Geoffroy's cat (*Leopardus geoffroyi*, Carnivora, Felidae) in Central Argentina

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ABSTRACT

Rodent prey remains recovered from Geoffroy's cat (*Leopardus geoffroyi*) scats were analyzed in order to identify taphonomic features produced by this predator. The analysis includes a year-long sampling discriminated by the seasons. Modifications produced by digestion are heavy. Taphonomic variables in samples discriminated by the seasons did not show major differences with respect to the total sample; thus, scats collected in any season clearly show the modifications on the bones of prey rodents made by Geoffroy's cats. The results presented here and its interpretation could be extrapolated to an analysis of zooarchaeological or paleontological assemblages.

1. Introduction

From a paleontological and zooarchaeological point of view, it is important to understand the processes and agents that may have participated in the formation of the fossil or archaeological record. In such a context, taphonomic analysis is of paramount importance. Taphonomic studies on recent accumulations produced by different predators may contribute to establish diagnostic characteristics of the fossil record (Andrews, 1990), and to determine if the bones in the site are present there due to the action of human beings or the action of carnivores. Therefore, some of the predators that inhabit central Argentina have already been evaluated in terms of the taphonomic changes they produce, including mammals such as the puma (*Puma concolor*), the hog-nosed skunk (*Conepatus chinga*) and the grey fox (*Lycalopex griseus)*, as well as some raptor birds (Martín and Borrero, 1997; Gómez, 2005; Gómez and Kauffmann, 2007; Montalvo et al., 2007, 2008; Mondini and Muñoz, 2008; Montalvo and Tallade, 2009, 2010). Moreover, Mondini (1995, 2000, 2001, 2003, 2004, 2005, 2008) analyzed the modifications that different carnivores, mainly foxes from Northern Argentina (*Lycalopex* spp.), produce on the bones of their prey.

Carnivorous mammals may directly carry the remains of their prey to their dwellings for consumption or they transport them there within their intestinal tract; thus, they incorporate additional bone material to archaeological or paleontological deposits (Andrews, 1990). It is possible that these remains end accumulated in latrines, or the scats may be deposited near the entrance of the predator's den, or the latter can be used to mark the carnivorous mammals' home range (Andrews and Evans, 1983; Mondini, 2000). They also scavenge from other sites removing some parts of the prey by transport and *in situ* destruction (Martín and Borrero, 1997).

Geoffroy's cat (*Leopardus geoffroyi*) is a small felid with a body mass of approximately 4 kg; scats of this species are usually accumulated in latrines located in tree trunks and caves (Soler et al., 2009). This little-known South American carnivore is distributed from Bolivia and southern Brazil throughout southern Argentina and Chile (Redford and Eisenberg, 1992). It mainly occupies dwells in arid and semiarid environments such as the Monte desert and the Patagonian steppe, but it can also be found in a wide range of habitat types including grasslands, open forests, and wetlands (Ximénez, 1975; Perovic and Pereira, 2006; Bisceglia et al., 2008). This species is nocturnal and solitary (Diaz and Barquez, 2002). It has been described as an opportunistic predator, feeding mainly upon introduced lagomorphs and small rodents in Patagonia (Johnson and Franklin, 1991; Novaro et al., 2000), on small rodents

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and waterbirds in the Pampas grasslands and Monte desert of Argentina (Canepuccia et al., 2007; Manfredi et al., 2004; Vuillermoz, 2001; Bisceglia et al., 2008; Teta et al., 2009), and mainly on small rodents in southern Brazil (Sousa and Bager, 2008).

Little is known about the modifications produced by this cat on the bones of its ingested prey. Some time ago, experimental assessment of these effects was taken place with rodents eaten by a captive Geoffroy's cat (Gómez, 2007). Using the taphonomic methodology proposed by Andrews (1990) and Fernández-Jalvo and Andrews (1992), the bone remains contained in this sample (2 scats) were analyzed, and the results suggested that this predator causes strong modifications in rodent bones; consequently the species was classified within the "extreme modification" category. Mondini (2005) mentioned the presence of Geoffroy's cat among the carnivorous species studied, but this author did not discriminate the specific effects caused by this predator on the bones of its prey. Álvarez et al. (2011) recently characterized the modification pattern on leporids non-ingested bones generated by captive Geoffroy's cat. The modifications were described in terms of anatomical representation, degree of breakage of bones and the presence of tooth marks. In their work, they described the preliminary analysis of remains recovered from scats found in the enclosure of the cats.

In this paper we present the results of the taphonomic analysis of the modifications on the bones of rodent prey produced by Geoffroy's cat. This assessment allows comparing the results obtained from this predator with data available in the literature concerning modifications on rodent bones produced by other carnivores. Our sample comprises numerous scats collected in Lihue Calel National Park in central Argentina during one year; the analysis was focused on both the materials as a whole and on possible seasonal differences among the samples. These materials were used in a previous analysis of the diet of Geoffroy's cat (Bisceglia et al., 2008).

2. Materials and methods

The studied sample was collected in Lihue Calel National Park (37°57′S 65°33′W; 9900 ha), La Pampa Province, Argentina (Fig. 1). This area is characterized by flat relief except for a large, isolated set of bare rocky hills. The vegetation is a mosaic of creosote bushes (genus *Larrea*), grasslands dominated by bunch grasses (e.g. *Stipa* spp.), and mixed shrub patches (e.g., *Condalia microphylla* and *Prosopis flexuosa*) (Cano et al., 1980). Fresh scats were collected seasonally from winter 2005 (mid-August) to autumn 2006 (mid-May). They were mainly collected from latrines regularly used by Geoffroy's cats (mostly at the base or crook of trees). Bisceglia et al. (2008) estimated that the analysed scat sample corresponded to at least 12 different Geoffroy's cat individuals.

The identification of the taxa present in each sample was performed by Bisceglia et al. (2008). All pellets contained vertebrate bones (Reptilia, Aves, Marsupialia, Rodentia, Lagomorpha), but only the remains of rodent bones are discussed in this paper. Materials were observed under a Leica Ms5 binocular microscope, and some of them were photographed under a Jeol 35 CF SEM at 8 kV at the *Unidad de Administración Territorial* (UAT) of the Scientific and Technological Center *CONICET Bahía Blanca* (CCT CONICET – BB), in Bahía Blanca, Argentina.

The total sample consisted of 179 scats. Each one was completely disaggregated until full separation of bone remains, horny material, hair, and feathers occurred. MNI (minimum number of individuals) and MNE (minimum number of elements) were calculated on both the whole sample and seasonal sample (*sensu* Badgley, 1986). The taphonomic analysis was made following the methodology proposed by Andrews (1990) and Fernández-Jalvo and Andrews (1992). This includes 1) assessment of the relative abundance of skeletal elements considering the representation of each one in the context of the minimum number of individuals: MNEi/(EixMNI) × 100, where MNEi is the minimum number of a given skeletal element in the sample and Ei is the expected number of that skeletal element in an individual; 2) calculation of indexes of the proportion of elements: (femur + humerus)/(mandible + maxilla); (femur + tibia + humerus + radius + ulna) × 8/(mandible + maxilla + molar) × 5 and (tibia + ulna)/(femur + humerus), and finally the relative proportion of isolated molars was calculated with reference to the number of empty alveolar spaces in mandibles and maxillae; 3) evaluation of the degree of breakage considering the complete remains separately from the fragments of long bones (proximal and distal epiphyses, and diaphysis); and 4) analysis of the degree of digestive corrosion, mainly on teeth (incisors and molars), proximal fragments of femora and distal parts of humeri.

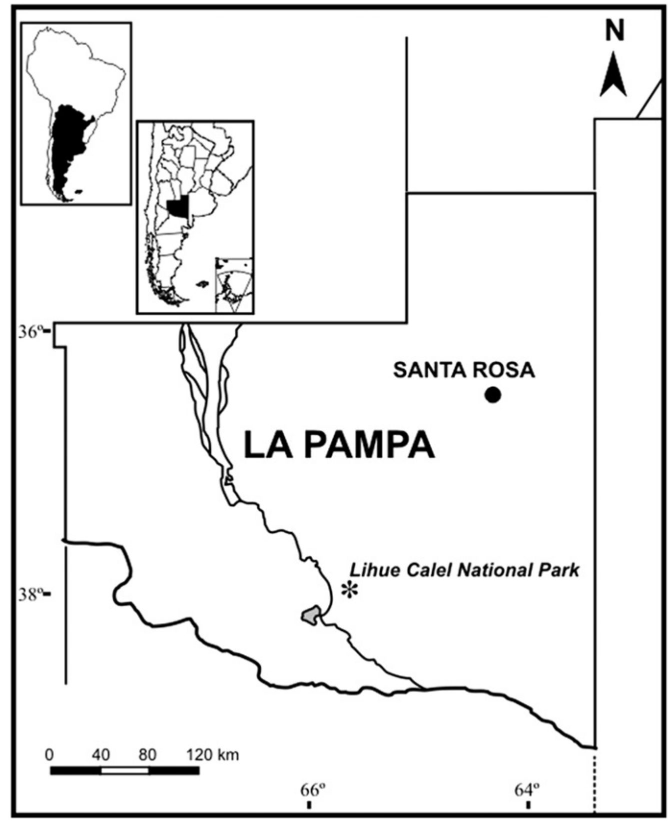

Fig. 1. Geographic location of Lihue Calel National Park in La Pampa province, Argentina.

Seasonal variation in MNE and relative abundance were analyzed by means of simple ANOVA and Tukey's tests to compare the means (Zar, 1996); seasonal variation in the degree of digestion was analyzed through double ANOVA. In all cases, variables were natural log-transformed due to the lack of normality in the data.

3. Taphonomic analysis

Table 1 presents the list of rodents recorded in the scats with their corresponding estimated body mass (*sensu* Tiranti, 1992). The remains of larger rodents, listed in the table as unidentified Caviidae, are very fragmented precluding their precise identification (Bisceglia et al., 2008). Rodents were the most frequent prey in all seasons; however, the samples also included remains of small reptiles, birds, marsupials and lagomorphs. Rodents were more abundant in autumn, when they represented 93.8% of the diet.

Table 1
Taxa identified in the sample, with estimations of their body mass.

Taxon	Body mass (g)
Akodon azarae	22
Akodon molinae	38
Calomys musculinus	16
Ctenomys cf. *C. azarae*	153
Graomys griseoflavus	61
Eligmodontia typus	17
Reithrodon auritus	74
Oligoryzomys longicaudatus	22
Unidentified Caviidae	~200

Akodon molinae, followed by *Calomys musculinus*, was the most consumed prey item (Bisceglia et al., 2008).

All 179 scats yielded 17,837 remains. The number of remains from the scats varied every season (Table 2). This includes horny remains, intervertebral discs and splinters or unidentifiable fragments, which were separated but not analyzed herein. On this study, 79.5% of all the recovered remains were analyzed.

MNE in the yearly sample was 14,181 skeletal elements. Relative abundance of identified skeletal elements was calculated, considering an MNI of 326 individuals (based on mandibles present in the sample), which resulted in an average of 41.66%. The same evaluation was made considering the seasonal samples (Table 2). Fig. 2 shows the percentage of the anatomical representation obtained for each skeletal element of rodents. Four peaks of over 50% are observed (mandibles, maxillae, femora and incisors), while the remaining anatomical elements have low values.

The average relative abundance of skeletal individuals did not significantly differ between seasons ($F_{(3,\ 60)} = 1.71$, $p > 0.15$) (Fig. 3A), but MNE was significantly different between seasons ($F_{(3,\ 60)} = 5.50$, $p < 0.01$); MNE was significantly higher in autumn and in winter compared to spring and summer ($P < 0.05$); but there were no significant differences between autumn and winter or spring and summer ($p > 0.10$) (Fig. 3B).

We used several indexes in order to analyze the relationship between cranial and postcranial elements (Table 3). The first two indexes give an idea of the state of preservation of cranial elements, as both show differences with respect to the postcranial elements. The value obtained from the third index indicates an important loss of distal elements compared to proximal ones. The last index (mandibular alveoli + maxillary alveoli/molars) shows the relative proportion of isolated teeth. Values lower than 100 imply that there has been a loss of mandibles and maxillae.

From the whole amount of remains recovered from the scats, 3586 corresponded to skull parts (not including isolated teeth); 59.78% of these remains were unidentifiable skull fragments. Among those that could be anatomically determined (1442 remains), no complete skulls or hemimandibles were found. We recovered 241 isolated rostra, of which 1.25% had both incisors preserved. Only two complete palates were found with 3 molars and one incisor, along with two palates with 4 molars each. Hemipalates with diverse degree of fragmentation and tooth preservation were frequent (548 remains), 21.35% of them lacked teeth and 32.30% corresponded to hemipalates with a single molar *in situ* (Fig. 4M).

No complete hemimandibles were found, but the ascending ramus is the only missing portion in most of them (Fig. 4N). Two sets of hemimandibles were found articulated. All teeth were missing in 16.90% of the hemimandibles.

In the yearly sample 1256 isolated molars were recovered. When the proportion of *in situ* and isolated molars was compared in the seasonal samples, greater tooth retention was observed in spring and summer (71 and 64% respectively), while the greatest loss of teeth from their alveoli was observed during winter. Only 3% of the total isolated molars were fractured or broken (Fig. 4L), while the rest were complete. The percentage of fractured or broken teeth was slightly higher among *in situ* molars. The total sample comprised 867 isolated incisors; from the analysis of each season, there was a result of greater retention of incisors in alveoli in the summer sample (44%) whereas the winter sample showed lower incisor retention.

It is noteworthy that, although the degree of fracture of the abovementioned skull elements was high, fragments of maxillae and hemimandibles with *in situ* molars were preserved allowing taxonomic determination of these remains.

The degree of fragmentation of postcranial elements was assessed using the femur, tibia, humerus and ulna (Table 4).

Table 2
Number of scats, number of specimens (NISP), minimal number of skeletal elements (MNE) of rodents, minimal number of individuals (MNI) evaluated and relative abundance of different skeletal elements for the annual sample and discriminated by season.

	Annual Sample		Spring		Summer		Autumn		Winter	
Scats	179		54		28		53		44	
NISP	17,837		2,304		1,966		8,023		5,544	
MNE (rodents)	14,181		1,744		1,599		6,808		4,030	
MNI	326		54		56		138		79	
	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.
Mandible	651	99.85	107	99.07	111	99.11	276	100	157	99.37
Maxilla	552	84.66	105	97.22	76	67.86	229	82.97	142	89.87
Scapula	194	29.75	24	22.22	24	21.43	97	35.14	49	31.01
Humerus	277	42.48	39	36.11	33	29.46	145	52.54	60	37.97
Radius	166	25.46	19	17.59	26	23.21	90	32.61	31	19.62
Ulna	181	27.76	23	21.30	21	18.75	87	31.52	50	31.65
Pelvis	254	38.96	29	26.85	22	19.64	140	50.72	63	39.87
Femur	471	72.24	69	63.89	62	55.36	202	73.19	138	87.34
Tibia	296	45.40	44	40.74	38	33.93	146	52.90	68	43.04
Vertebra	3,352	28.56	387	19.91	359	17.81	1,708	34.38	898	31.58
Incisor	867	66.49	137	63.43	103	45.98	340	61.59	287	90.82
Molar	1,256	32.11	142	21.91	165	24.55	566	34.18	383	40.40
Metapodial	4,789	26.23	522	17.26	465	14.83	2,318	29.99	1,484	33.54
Calcaneus	130	19.94	17	15.74	17	15.18	60	21.74	36	22.78
Astragalus	122	18.71	17	15.74	13	11.61	67	24.28	25	15.82
Ribs	623	7.96	63	4.86	64	4.76	337	10.18	159	8.39
Average		41.66		36.49		31.47		45.5		45.19

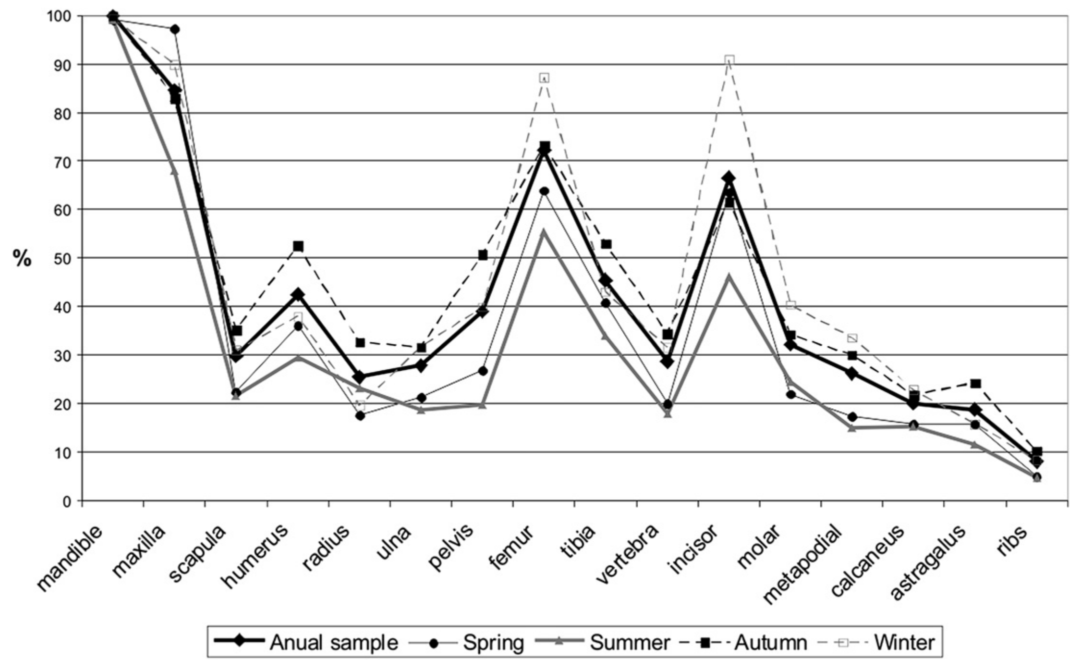

Fig. 2. Comparison of percentages of relative abundance of different anatomical elements by season and for the annual sample.

On average, only 22.29% of these elements were complete; in the case of the ulnae, complete bones predominated over other fragments in all seasons. Distal humeral fragments and proximal tibiae and femora were abundant. The complete most distal autopodial elements (metapodials and phalanges) were also preserved in high proportion. Forty-two scats contained articulated parts of the autopodium as well as vertebrae. In addition to the above-mentioned articulated hemimandibles, other articulated elements were found in the sample: three tibiae articulated with the respective femora, one femur articulated with the pelvis, and an entire articulated forelimb in one scat.

Degree of digestion was assessed on the molars, incisors, proximal femora and distal humeri (Table 5 and Fig. 4). To varying degrees, all skeletal elements showed some evidence of rounding and corrosion due to digestion, except in the case of those remains still covered by skin and hair that undoubtedly acted as protective structures.

All teeth exhibited some degree of corrosion due to digestion, as indicated by Andrews (1990) on carnivorous mammals.

The seasons had no influence on the percentage of bones with different types of digestion ($F_{\text{Season vs Digestion }(9,\ 80)} = 0.94$, $p > 0.45$); however, significant differences were found between seasons ($F_{(3,\ 80)} = 7.69$, $p < 0.001$) and degree of digestion ($F_{(3,\ 80)} = 4.50$, $p < 0.001$). Most evidences of digestion were found in autumn, with high percentages in every category ($p < 0.05$); spring, summer and winter did not show significant differences on any of the above-mentioned categories ($p > 0.10$). Heavy and moderate degrees of digestion were significantly higher than the extreme type ($p < 0.05$); however, the values for light degree of digestion were similar to the other three types ($p > 0.10$) (Fig. 5).

We did not identify any skeletal elements or bone fragments with tooth marks or grooves produced by teeth scratching on compact bone, but spiral fractures (*sensu* Marshall, 1989) were observed in long bones (Fig. 4B,E,F), resulting from fracture of the latter during mastication.

4. Discussion

The analyses of the diet of Geoffroy's cat in La Pampa province that was based on the remains found in scats have shown that the main prey for this species are small rodents with a body mass of less than 200 g (Bisceglia et al., 2008; Teta et al., 2009).

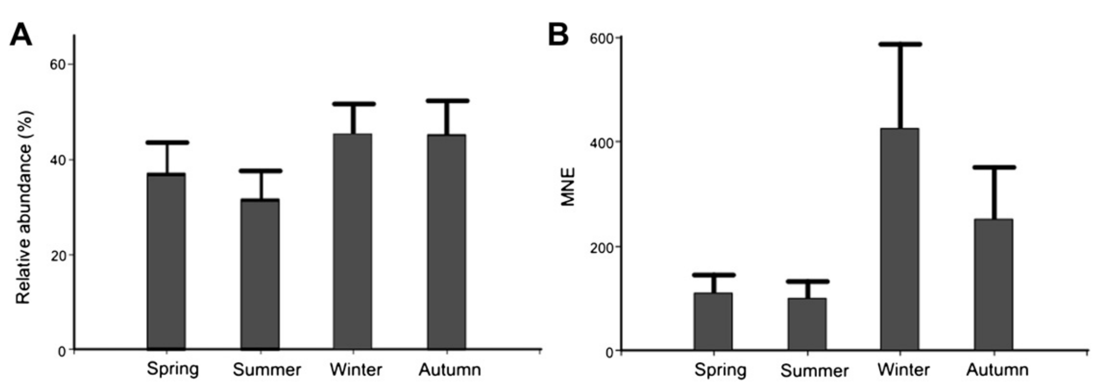

Fig. 3. (A) Mean relative abundance of skeletal elements by seasons; (B) Minimal number of elements by seasons.

Table 3
Indexes calculated for the annual sample and by season.

	Annual sample	Spring	Summer	Autumn	Winter
pc/c*8/5	90.51%	87.68%	81.82%	100.09%	81.41%
(Humerus + femur)/(mandible + maxilla)	62.18%	50.94%	50.80%	68.71%	66.22%
(Tibia + ulna)/(femur + humerus)	61.76%	58.33%	67.37%	68.01%	50.00%
Mandibular alveoli + maxillary alveoli/molars	77.71%	113.38%	70.30%	73.67%	73.63%

Until now, little was known about the digestive modifications produced by Geoffroy's cats on prey bones. An experimental study that consisted on rodents eaten by a Geoffroy's cat in captivity suggested, on the basis of two recovered scats, that the prey remains generated by this cat fell within the 'extremely modified' category (Gómez, 2007). Álvarez et al. (2011) experimentally analyzed leporids non-ingested bone modifications produced by this cat, and they mentioned some of the results of the preliminary evaluation of remains recovered from scats obtained from their experiment. It is worthy of remark that the remains of prey studied by these authors are remains of adults and sub adults European domestic rabbits (*Oryctolagus cuniculus*) with an average of an estimate body mass of 3 kg (Álvarez et al., 2011). This body mass is bigger than the average body mass of the rodent ingested by Geoffroy's cats in Lihue Calel.

In this study, the MNI of 326 consumed individuals was calculated from the analysis of more than 14,000 skeletal elements recovered from 179 scats. Most scats contained skeletal elements belonging to one or two individuals; however, some scats contained remains corresponding to as many as four to seven individuals. These data does not go with the suggestion of Andrews (1990) who indicated that the scats of felid taxa showed that few bones and teeth of their prey endured the digestive process. When Montalvo et al. (2007) studied the content of puma (*P. concolor*)

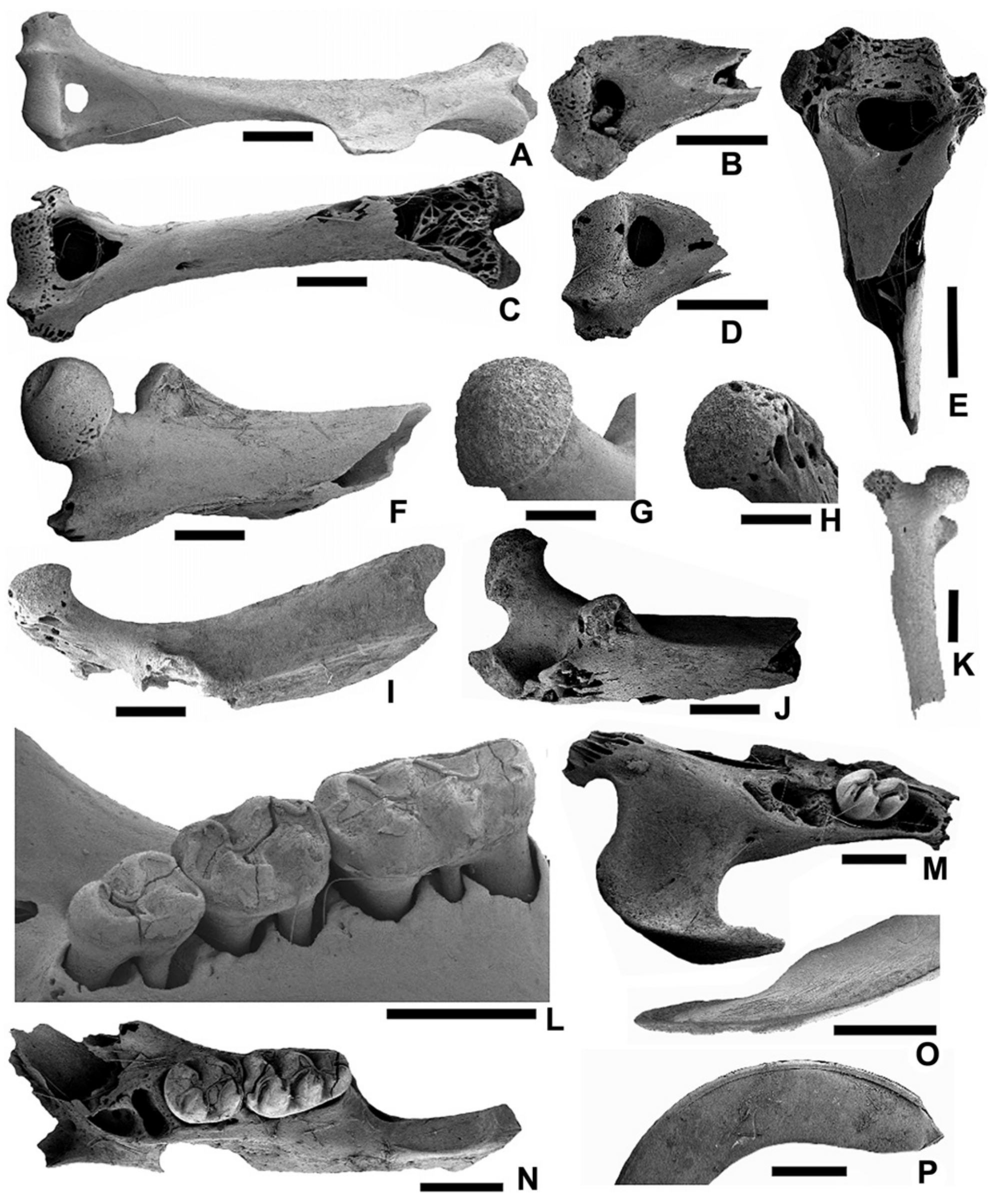

Fig. 4. (A–E) Humeri with different degree of digestion; (F–K) Femora with different degree of digestion; (L) hemimandible with molars *in situ* (molars with light degree of digestion and breakage); (M) hemipalate with 1 molar *in situ*; (N) hemimandible with molars *in situ*; (O–P) incisors with different degree of digestion. Scale bars = 1 mm.

Table 4
Percentual breakage of postcranial elements in seasonal and annual samples.

	Spring	Summer	Autumn	Winter	Total
Femur					
% Complete	5.80	6.45	6.93	1.45	5.10
% Proximal	60.87	50.00	64.36	61.59	61.15
% Shaft	7.25	8.06	4.46	10.87	7.22
% Distal	26.09	35.48	24.26	26.09	26.54
MNE	69	62	202	138	471
Humerus					
% Complete	46.15	45.45	42.76	26.67	40.07
% Proximal	7.69	12.12	13.79	23.33	14.8
% Shaft	0	0	1.38	1.67	1.08
% Distal	46.15	42.42	42.07	48.33	44.04
MNE	39	33	145	60	277
Tibia					
% Complete	15.91	15.79	15.75	4.41	13.18
% Proximal	50	44.74	54.79	41.18	49.66
% Shaft	9.09	13.16	10.96	30.88	15.54
% Distal	25	26.32	18.49	23.53	21.62
MNE	44	38	146	68	296
Ulna					
% Complete	56.52	52.38	60.92	44	54.70
% Proximal	39.13	28.57	34.48	52	39.23
% Shaft	0	0	0	0	0
% Distal	4.35	19.05	4.6	4	6.08
MNE	23	21	87	50	181

scats obtained an important sample of rodent bone remains among other larger prey, and Matthews (2006) recovered abundant micromammal remains in an analysis of samples from diverse small carnivores (including felids).

Regarding taxonomic composition, Bisceglia et al. (2008) noted that the composition in autumn differs from that of the remaining seasons because in the former season most of the diet is made up of small rodents, while during the rest of the year the diet of this species also includes other trophic categories (mainly birds and reptiles). This is made evident by the high values of MNI (138) and MNE found (more than 6800 items) in the autumn sample.

The analysis of relative abundance, considering the total sample of Geoffroy's cat scats, was compared with the mean values for small carnivores (Fig. 6) obtained by Andrews (1990) and Matthews (2006). There are similarities between all the samples; there are good preservation of mandibles, maxillae, humeri, femora and incisors. The average relative abundance of recovered skeletal elements was similar in all cases; mandibles and incisors were better represented than maxillae and molars, respectively. In the case of scats evaluated by Álvarez et al. (2011), the average of relative abundance was 34%. In these scats there was a good representation of skeletal elements that were absent or scarce in the non ingested sample, such as phalanges. Some elements such as mandibles that were more frequent in this last sample were scarce in scats sample.

The indexes that allow analyzing the representation of cranial and postcranial elements show a deficit of the latter. When evaluating the pc/c index, Gómez (2007) obtained a result indicating abundance of cranial materials, but this author pointed out that such a result was linked to a large amount of isolated molars obtained in the samples, as no maxillae or mandibles had been found.

Among limb components, the index showed a loss of distal elements, in agreement with the results of Andrews (1990) for carnivores in general. The index evaluating the relative proportion of isolated molars showed that there was little destruction of mandibles and maxillae in the sample. Nevertheless, in the spring sample the index was only slightly greater than 100, denoting a loss of molars in that case.

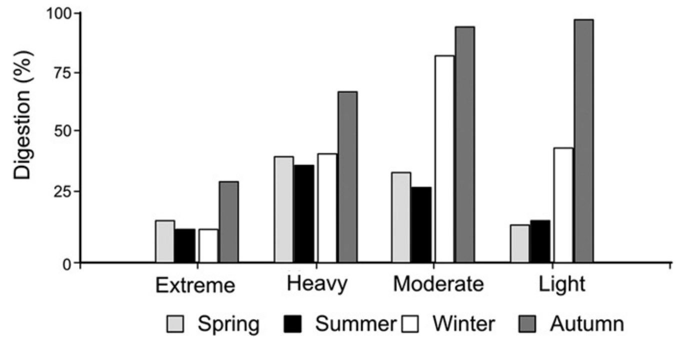

Fig. 5. Percentage of remains in each digestive category grouped by season.

Table 5
Degree of digestion of postcranial elements and teeth present in samples by season and in the annual sample.

	MNE	Light	%	Moderate	%	Heavy	%	Extreme	%
Spring									
Femur	47	18	38.30	13	27.66	10	21.28	6	12.77
Humerus	38	6	15.79	12	31.58	10	26.32	10	26.32
Incisor	199	3	1.51	56	28.14	77	38.69	63	31.66
Molar	482	77	15.98	169	35.06	199	41.29	37	7.68
Summer									
Femur	34	12	35.29	11	32.35	7	20.59	4	11.76
Humerus	30	7	23.33	8	26.67	9	30.00	6	20.00
Incisor	185	10	5.41	43	23.24	88	47.57	44	23.78
Molar	450	90	20.00	150	33.33	169	37.56	41	9.11
Autumn									
Femur	144	75	52.08	35	24.31	15	10.42	19	13.19
Humerus	123	51	41.46	37	30.08	17	13.82	18	14.63
Incisor	521	64	12.28	187	35.89	171	32.82	99	19.00
Molar	1,259	492	39.08	401	31.85	275	21.84	91	7.23
Winter									
Femur	91	42	46.15	19	20.88	17	18.68	13	14.29
Humerus	53	16	30.19	17	32.08	10	18.87	10	18.87
Incisor	344	39	11.34	156	45.35	109	31.69	40	11.63
Molar	806	222	27.54	386	47.89	166	20.60	32	3.97
Total									
Femur	316	147	46.52	78	24.68	49	15.51	42	13.29
Humerus	244	80	32.79	74	30.33	46	18.85	44	18.03
Incisor	1,249	116	9.29	442	35.39	445	35.63	246	19.70
Molar	2,997	881	29.40	1,106	36.90	809	26.99	201	6.71

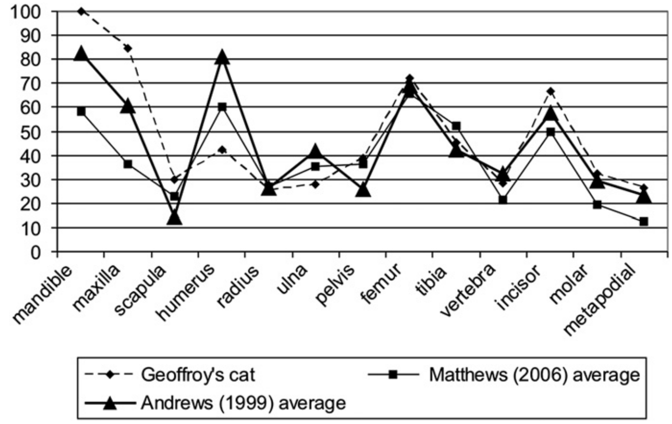

Fig. 6. Average relative abundance of skeletal elements in Geoffroy's cat scats compared with mean data for carnivores from Andrews (1990) and Matthews (2006).

Table 6
Categorization of Geoffroy's cat effects on prey remains according to different analyzed variables.

	Categories				
	1	2	3	4	5
Relative abundance				■	
pc/c				■	
Distal element loss			■		
Breakage of postcrania				■	
Breakage of skull					■
Loss of zygomatic processes					■
Maxillary tooth loss			■		
Breakage of mandibles				■	
Mandibular tooth loss				■	
Proportions isolated teeth				■	
Breakage of teeth			■		
Digestion of molars			■		
Digestion of incisors			■		
Digestion of postcrania			■		

The degree of breakage in all skeletal elements was high, in agreement with the high degree of breakage that occurs during mastication (Andrews, 1990). This especially affects cranial elements; whole skulls, mandibles or maxillae were not found, but portions of hemipalates and hemimandibles with teeth in the alveoli were preserved. Among the postcranial elements, complete metapodials and phalanges were frequent; the small size and high bone density of these elements may have allowed their preservation. Humeri and ulnae are the best preserved among the analyzed bones, shown by the fact that there is a high percentage of complete elements of these kinds (Fig. 4A, B). Previous works have shown that it is frequent to find the most distal elements of rodent limbs still articulated, even with skin and hair, in the scats of foxes, pumas and skunks (Mondini, 2000; Montalvo et al., 2007, 2008). Mondini (2000) noted that these skeletal parts are not often chewed because of their lack of nutritious materials. Álvarez et al. (2011) did not find any complete long bone in the scats evaluated in their experimentation and they linked this characteristic with the size relationship between predator and prey.

As previously indicated, all remains show evidence of rounding and digestive corrosion to various extents. This attribute was evaluated in detail on 4806 skeletal elements (Table 5); modifications were moderate in 35.37%, heavy in 28.08%, light in 25.47% and extreme in 11.09%. In this sample there are not remains with tooth marks. But, Álvarez et al. (2011) indicated that 1.6% of all the remains recovered from scats sample present tooth marks. This characteristic could be related to the size of the prey, too.

The distribution of prey along the four seasons showed higher MNI and MNE in autumn, as rodents are more common in the diet of these cats during this season (Bisceglia et al., 2008). It is also during this season when there is a greater amount of skeletal elements with evidence of light and moderate modification. In the whole sample, moderate degrees of digestion are prevalent, but light and heavy modifications are frequent. Items in the light and moderate categories were more frequent in autumn and winter than in spring and summer.

When analyzing the modifications produced by small mammals on rodent incisors, Matthews (2006) proposed a new categorization scheme that includes 6 classes of modification, ranking from 0, for no evidence of digestion, to 4, for extreme modifications. This scheme also includes a new category 1a for incipient modification of incisor dentine. In an analysis of small African carnivores, she found a high total percentage (close to 50%) of incisors (both *in situ* and isolated) that fell into categories 1 and 1a, and about 34% corresponding to category 2 (light and moderate modifications). Her data goes with those obtained from Geoffroy's cat in the fact that in both cases, no incisors were found showing no evidence of digestion (category 0). However, in the African samples, the percentage of incisors with light evidence of digestion was greater when compared with the Geoffroy's cat sample, in which the percentage for this category of modification did not reach 10%; even in the autumn and winter samples which showed somewhat higher percentages, this result did not reach 13%. On the other hand, in the Geoffroy's cat samples more than 19% of the incisors show extreme digestion, whereas in the case of small African carnivores this category reached a result of 1.5%.

The results obtained in this work contradict previous assessments that had been made on representatives of the family Felidae, that had been generally considered to produce extreme modifications on prey bones due to the effects of digestion (Andrews and Evans, 1983; Andrews, 1990). When molar corrosion for digestion was evaluated, Andrews (1990) based his work on arvicolids rodents and suggested that there were differences when other taxa of rodents were analyzed. Andrews and Fernández-Jalvo (2011) and Demirel et al. (2011) recently analyzed three groups of rodents based on their molar morphologies and described different degrees of digestion produced by the same predator over each group. In the case of the rodent prey of Geoffroy's cat the morphology of molars resembled those of European murids and could be less affected by digestive acids. Moderate and light degree of digestions on 1987 molars (66.30% of all molars evaluated for digestion) were the more frequent categories. The contradiction that appeared in the assessment of the modifications produced by representatives of the family Felidae could be explained considering these differences.

5. Conclusions

Andrews (1990), based on an analysis of remains from scats, pointed out that carnivores significantly damage prey bones because they are not only modified when they go through the digestive tract, but they are also greatly destroyed during mastication. The degree of breakage in the studied sample was very high; however, it was possible to taxonomically identify several small sigmodontine rodent species and also anatomically assess their skeletal elements given that many of the remains are well preserved. Difficulties with both anatomical and taxonomical determination only arose in the case of larger sized rodents (v.g. Caviidae). Previous works on other carnivores (Mondini, 2005; Montalvo et al., 2007, 2008) suggested that the ability to taxonomically determine prey remains decreases as the body mass of the prey increases; our results support this idea.

Different taphonomic variables used to analyze anatomical representation, fragmentation and modifications due to digestion were evaluated for the preserved remains. From the results described and discussed above, and considering the total sample, we conclude that the scats of Geoffroy's cat preserve enough skeletal elements from rodents to allow analysis of the type of modifications exerted on these bones and taphonomically characterize this species. The average of the relative abundance of remains was high, including good representation of mandibles, maxillae, femora and isolated incisors. Cranial elements were more abundant, with high proportion of isolated teeth. Among the postcranial elements, proximal limb bones were predominant with respect to distal parts. The degree of breakage was very high in all bones, especially in the axial skeleton, and complete appendicular elements (mainly humeri and ulnae, among those analyzed in this work) were preserved. Regarding corrosion due to digestion, it was mainly moderate and heavy, and only 11% of the assessed remains present extreme digestion.

Using the methodology proposed by Andrews (1990), these results allow assigning Geoffroy's cat to the "heavy modification" category with respect to micromammal remains (Table 6). This analysis also indicates that the modifications produced by this species include variables from categories 3, 4 and 5, but the latter (extreme) are the least frequent. Table 6 indicates the respective categories for the different attributes that were analyzed.

When the variables in the samples were considered by season, they did not show important differences with respect to the total sample, and consequently each of them can clearly show the modifications on rodent prey produced by Geoffroy's cat. The greatest differences were mainly identified in the autumn sample, which included the highest amount of prey and also the highest average of relative abundance; the pc/c index was closer to one and remains with light evidence of digestion were abundant. Bone breakage in this season did not show important differences as regards the values of other seasons. The presence of a high amount of remains with light evidence of digestion could indicate a fast going through the digestive system, and this phenomenon could be related to prey availability rather than to an intrinsic feature of this predator.

The results of the taphonomic analysis of the rodent bone sample from Geoffroy's cat scats are encouraging, as they can be used as a present-day analogue in the assessment of fossil accumulations.

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