

The Role of *Bubo virginianus magellanicus* as Rodent Bone Accumulator in Archaeological Sites: A Case Study for the Atuel River (Mendoza, Argentina)

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ABSTRACT Micromammalian bone assemblages from modern pellets of the strigiform *Bubo virginianus magellanicus*, from the upper Atuel River (southern Mendoza, Argentina), were taphonomically analysed. The results allow us to place *B. v. magellanicus* in the category of intermediate modification (Category 2). This sample has also been compared with results from other members of this genus, in order to classify *B. v. magellanicus* as a taphonomic agent. The participation of the *Bubo* species in archaeological accumulations has been documented, but in Argentina, the role of *B. v. magellanicus* has been reported up to the present. It is partly because of the sequence of one archaeological site in the south of Mendoza Province called Laguna El Sosneado-3 (LS-3). However, considering the absence of a current taphonomic model of this owl, this participation was mentioned as a hypothesis. In the current investigation, archaeological and modern samples have been compared. The results indicate that the skeletal element assemblages recovered from LS-3 were accumulated by strigiform birds. Taphonomical evidence of light modifications on units I and IV indicates that *Tyto alba* (Category 1) was probably the main species involved in these units, whereas the taphonomical evidence on skeletal element assemblages recovered from units II and III suggests the action of a strigiform with a major category of modification such as *B. v. magellanicus*. Copyright © 2015 John Wiley & Sons, Ltd.

Key words: archaeological record; Argentina; *Bubo virginianus magellanicus*; rodents; Southern Mendoza; taphonomy

Introduction

In Argentina, as in many other places, several archaeological sites are very rich in small rodent bones (Pardiñas, 1999; Fernández, 2012; and references therein). Different processes are responsible for the formation of these accumulations, and it is interesting to know what agents may have been involved in such formation. The natural disaggregation processes of the pellets produced by raptor birds and faeces of carnivore mammals are among the most important ones (Andrews, 1990). The taphonomic analyses performed

on accumulations produced by modern predators help to establish the diagnostic features that each one prints on the bones of its prey (Andrews, 1990). According to the evaluations made on the relative abundance of prey bones and on the breakage and corrosion degree produced by digestion observed on bones and teeth, Andrews (1990) has established three groups of predators. The nocturnal raptors are the ones that produce fewer changes, while diurnal raptors and mammalian carnivores cause major changes.

Taphonomic studies based on accumulations generated by different species of Strigiformes have received much attention in many parts of the world (Andrews, 1990). In Argentina, these studies began in the 1990s, and they have increased over the last few years due to the need for an actualistic local model for comparison

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with the archaeological record (e.g. Pardiñas, 1999; Gómez, 2005, 2007; Fernández *et al.*, 2009; Montalvo & Tejerina, 2009; Rudzik *et al.*, 2013).

Moreover, we can expect an overlapping of records accumulated by birds of prey that often make nests and roosts on rock shelters as different species of *Tyto* and *Bubo* do with those records generated by humans (Fernández, 2012). In this regard, the taphonomic differentiation of these agents is interesting for zooarchaeology, because it can provide relevant information about the predator/prey interaction and about the environmental conditions at the time of the deposition of the fossil aggregate (Stahl, 1996). In this sense, many micromammal species are used as proxies to trace palaeoenvironmental models (e.g. Andrews, 1990; Fernández, 2012). Hence, a comprehensive taphonomic approach of these raptor birds is important to detect specific patterns for identifying micromammal assemblages associated with the archaeological record.

A single species of the genus *Bubo* inhabits South America, *Bubo virginianus* [*Bubo virginianus magellanicus* (Magellanic horned owl) with Andean Patagonian distribution, from central Peru up to southern Chile and Argentina, and *Bubo virginianus nacurutu* at the east of the Andean Cordillera, from central Brazil to central Buenos Aires Province in Argentina]. *B.v. magellanicus* (650–1500 g) inhabits open environments and woodlands, building their nests on rock shelters, cliffs, trees and shrubs (Marks *et al.*, 1999). It is a crepuscular nocturnal and opportunistic raptor, whose diet is mainly based on micromammals under 150 g, although the size of its prey varies between 15 and 300 g; it also predated on birds, amphibians and insects (Nabte *et al.*, 2006).

From a taphonomical standpoint, modern accumulations produced by representatives of the genus *Bubo* have been evaluated by Dodson & Wexlar (1979), Korth (1979), Kusmer (1990), Hoffman (1988), Andrews (1990), Dauphin *et al.* (2003), Gómez (2005, 2007) and Reed (2005) studying the micromammals included in pellets. Bochenski *et al.* (1993), Bochenski & Tomek (1997), Laroulandie (2000, 2002) and Fernández *et al.* (2009) have evaluated bird remains. Pinto Llona & Andrews (1999) have studied amphibians' remains, whereas Russ (2010) has studied fish remains.

The participation of the *Bubo* species in archaeological accumulations has been documented. The differentiation of their taphonomic patterns from those of human activity has been useful for the interpretation of zooarchaeological contexts (e.g. Hockett, 1991, 1995; Sanchis Serra, 2000; Laroulandie, 2002; Yravedra, 2004; De Cupere *et al.*, 2009; Lloveras *et al.*, 2009, 2012; Russ, 2010). Most of these studies have been focused on the evaluation of leporid assemblages.

However, in Argentina, only the participation of *B.v. magellanicus* has been reported up to now, partly because of the sequence of one archaeological site in the south of Mendoza Province called Laguna El Sosneado-3 (LS-3; Fernández, 2012; Otaola *et al.*, 2014). Considering the absence of a current taphonomic model of this owl, the authors mentioned earlier have kept this conclusion as a hypothesis, based on the taphonomic comparison with other subspecies that inhabit the plains (*B.v. nacurutu*). In the present investigation, there is an opportunity to contrast this hypothesis; such a contrast is based on a taphonomic analysis and comparison with a rodent bone assemblage from modern pellet sample produced by *B.v. magellanicus*, recovered near the archaeological site. The modern sample has also been compared with other members of this genus, in order to classify *B.v. magellanicus* as a taphonomic agent, following the categories established by Andrews (1990).

Archaeological site

Laguna El Sosneado-3 is located in the upper valley of Atuel River (34°51'S, 69°53'W; 2100 m above sea level; Figure 1), in the Andes Cordillera in the south of Mendoza Province. It is a large rock shelter built by basalt and andesite, 40 m above El Sosneado lagoon level. It is about 12 m wide at the mouth, is 6 m long and covers 45 m². Excavations in the LS-3 cave were conducted during 1992 and 2000 (Otaola *et al.*, 2014). Two archaeological squares covering 3 m² were dug, and the bedrock was reached at a depth of 1.05 m (Otaola *et al.*, 2014).

The sequence was rich in microvertebrate remains, but other zooarchaeological remains were also obtained, such as carnivores and camelids. This record indicated a palimpsest, with the participation of strigiform birds in the accumulation of microvertebrates, and both carnivores and humans in the deposition of medium and large-sized vertebrates (Fernández, 2012; Otaola *et al.*, 2014). It appeared that this site had sporadic human occupations towards the end of Late Holocene. Apparently, it was used as a shelter during bad weather conditions, where scarce cultural and subsistence activities took place (Otaola *et al.*, 2014). The small mammal records of LS-3 have revealed a great environmental stability through the sequence of LS-3 (Fernández, 2012).

Otaola *et al.* (2014, Figure 1) documented four stratigraphic units 'U' spanning the last 2100 BP: U1 includes the upper deposits (0- to 25-cm depth); it is composed by sandy sediments with ash and thin clasts. Although there are no radiocarbon dates, the finding of dung from the domestic and exotic goat (*Capra hircus*) suggests that the upper part of this unit is related to

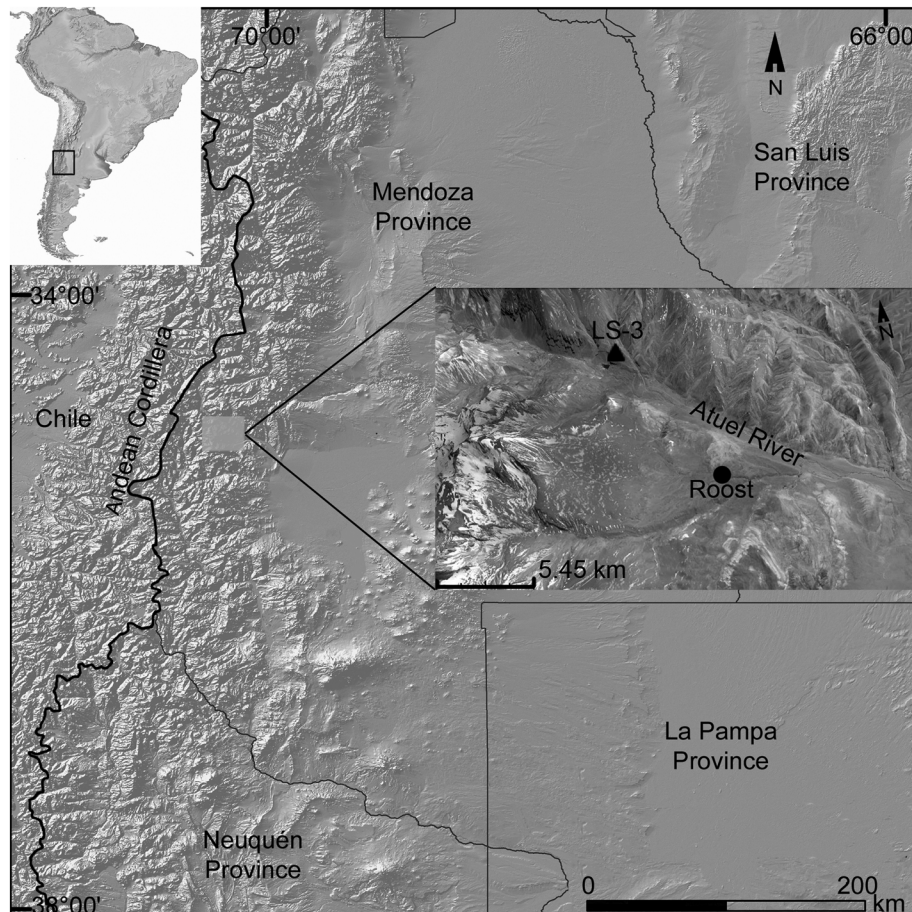


Figure 1. Map of Mendoza Province, Argentina, showing the details of the studied area including the Laguna El Sosneado-3 (LS-3) archaeological site (triangle) and roost of *Bubo virginianus magellanicus* (dot).

historical and modern times. UIII comprises the upper part of the middle deposits (25- to 50-cm depth); it is formed by clayey and sandy sediments with dry clasts. Charcoal sample was dated 659 ± 51 years ¹⁴C BP (574–663 cal. BP; lab code AA90286). UIII includes the lower part of the middle deposits (50- to 75-cm depth); it is mainly composed by thin sandy sediments with high humidity. Charcoal sample was dated 1806 ± 51 years ¹⁴C BP (1659–1807 cal. BP; lab code AA90287). UIV covers the lower deposits (75- to 105-cm depth); it presents similar sedimentary characteristics as those of UIII. Charcoal sample was dated 2145 ± 41 years ¹⁴C BP (2074–2275 cal. BP; lab code AA58291).

Materials and methods

Modern sample

Pellets produced by *B.v. magellanicus* (84) were recovered in January 2007, in a rock shelter of Panchino

creek, a tributary of the upper Atuel River (Arroyo Panchino 1; 34°56'45"S, 69°50'55"W; 2341 m above sea level), 13 km south from LS-3 (Figure 1). All the pellets yielded bones of amphibians and reptiles (1.5%), birds (1.5%) and mammals [marsupials (0.8%) and rodents (96.2%)]. Only rodents were analysed on this paper. The pellets were disaggregated manually after immersing them in water for a few seconds; all the anatomical elements were separated with surgical instruments. Rodent sample is formed by 3803 skeletal remains. Materials are housed in the archaeological collection of the Museo de Historia Natural de San Rafael (MHNSR-0098).

Archaeological sample

The microvertebrate sample of LS-3 was composed by 5869 skeletal remains, including reptiles (4.4%), birds (1.4%) and mammals (94%). Nonetheless, the present study included the rodent sample. The sediments that contained microvertebrates were sieved

through a 2-mm-sized mesh. Microvertebrates are housed in the archaeological collection of the Museo de Historia Natural de San Rafael (MHNSR-000006).

Taphonomic model

The minimum number of specimens (NISP), minimum number of individuals (MNI) and minimum number of skeletal elements (MNE) were calculated. For calculating the MNI of rodents, the mandibles were used.

The taphonomic analysis followed the methodology proposed by Andrews (1990) and Fernández-Jalvo & Andrews (1992). This includes an assessment of the relative abundance of skeletal elements considering the representation of each one of them in the context of the MNI [$MNE_i/(E_i \times MNI) \times 100$] and calculation of indexes for the proportion of cranial and postcranial elements: (pc/c), $[(femora + tibiae + humeri + radii + ulnae) \times 8 / (mandibles + maxillae + molars) \times 5]$; (f + h/md + mx), $[(femora + humeri) / (mandibles + maxillae)]$; (t + u/f + h), $[(tibiae + ulnae) / (femora + humeri)]$; and (alv/m), $[(mandibular\ alveoli + maxillary\ alveoli) / molars]$. The degree of the completeness of the skull, mandible and postcranial bones was evaluated. Average percentages

of fragmentation [TNB, total number of bones (=MNE); NBB, number of broken bones; PF, percentage of fragmentation = NBB/TNB] were calculated (Souffou et al., 2012). The analysis of digestive corrosion was performed on teeth, femora and humeri.

Bones and teeth were observed under a stereomicroscope, and some of them were photographed under a scanning electron microscope at the *Unidad de Administración Territorial* of CONICET, Bahía Blanca, Argentina. Taxonomic determinations were made based on cranial remains, using specimens of the Mammal Collection of the Museo de La Plata and bibliographical sources for comparison (e.g. Fernández et al., 2011).

Results

Modern sample

The rodent sample was composed by a total NISP of 3803 (Table 1). Only 1.2% of it could not be anatomically determined. In terms of MNI%, the sigmodontine rodents *Eligmodontia* sp. (35.2%), *Euneomys chinchildoides* (22.4%), *Abrothrix olivacea* (olive grass mouse) (14.4%), *Abrothrix hirta* (3.2%), *Phyllotis xanthopygus* (10.4%) and

Table 1. NISP, MNI, MNE, relative abundance and indexes evaluated from *Bubo virginianus magellanicus* and Laguna El Sosneado-3 archaeological site

	<i>B. v. magellanicus</i>		Unit 1		Unit 2		Unit 3		Unit 4	
	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.	MNE	Rel. ab.
NISP	3803		1568		1173		1686		1100	
MNI	111		76		64		72		61	
Maxillae	178	80.2	59	18.5	49	19.3	71	26.3	34	16.3
Mandibles	222	100.0	102	32.1	79	31.1	89	30.7	70	33.7
Scapulae	78	35.1	39	12.3	36	14.2	46	17	27	13
Humeri	175	78.8	119	37.4	92	36.2	105	38.9	68	32.7
Radii	159	71.6	50	15.7	45	17.7	64	23.7	40	19.2
Ulnae	149	67.1	63	19.8	58	22.8	89	33	43	20.7
Pelves	161	72.5	83	26.1	64	25.2	88	32.6	44	21.2
Femora	205	92.3	75	23.6	92	36.2	90	33.3	67	32.2
Tibiae	201	90.5	162	50.9	103	40.6	124	45.9	78	37.5
Vertebrae	485	12.1	330	6.9	207	5.4	414	10.2	263	8.4
Incisors	59	13.3	154	24.2	88	17.3	130	24.1	72	17.3
Molars	58	4.3	40	2.1	26	1.7	53	3.3	48	3.8
Metapodials	1082	12.8	186	5.5	163	6	187	6.2	154	6.8
Astragali	17	7.7	26	1.3	0	0	10	3.7	12	5.8
Calcanea	25	11.3	4	8.2	31	12.2	28	10.4	23	11.1
Ribs	407	15.3	44	1.2	20	0.6	53	1.6	38	1.5
MNE total	3661		1536		1153		1641		1081	
Average rel. ab.	47.8		16.8		16.8		20		16.5	
pc/c	310.6		373.3		405.2		567.8		311.6	
(f + h)/(md + mx)	95		120.5		143.7		121.8		129.8	
(t + r)/(f + h)	94.74		109.3		80.4		96.4		87.4	
alv/mol	81.59		61		62.4		54.8		57.1	

NISP, minimum number of specimens; MNI, minimum number of individuals; MNE, minimum number of skeletal elements; rel. ab., relative abundance.

Loxodontomys micropus (3.2%) dominated the studied sample. The hystricognath rodents *Ctenomys* sp. (11.2%) were not so dominant.

Table 1 shows the MNE, average of relative abundance and indexes evaluated.

In the sample, the losses of teeth from maxillae, premaxillae and mandibles were low. Most of the skull fragments corresponded to maxilla without zygomatic arches, but 49 skulls were more complete. Most mandibles were complete (47.3%), but some of them did not have the articular region (43%) (Figure 2).

The results of evaluation of the fragmentation of skeletal elements are shown in Table 2, and the degree of breakage of long bones is present in Table 3.

In this sample, more than 32% of skeletal elements and teeth do not present evidence of digestion; sigmodontine rodents stand out with moderate and strong signals of digestive corrosion (Table 4). The molars of *Ctenomys* sp. showed little evidence of action of digestive acids. The presence of dentine and even enamel, cracked by digestive action, was frequent in molars. Only a few specimens of sigmodontine

presented evidence of extreme modifications, indicated by broken edges, which were rounded and polished, with holes in certain areas of the bone (Figure 2).

Archaeological sample

The rodent assemblages were composed by a total NISP of 5527 (Table 1). In terms of MNI%, the Sigmodontinae rodents were composed by an estimated body mass of less than 80 g: *P. xanthopygus* (yellow-rumped pericote) (UI = 27.6%; UII = 40.6%; UIII = 33.3%; UIV = 47.5%), *E. chinilloides* (chinchilla rat) (UI = 31.6%; UII = 29.7%; UIII = 26.4%; UIV = 26.2%), *Eligmodontia* sp. (silky mouse) (UI = 11.8%; UII = 15.6%; UIII = 13.9%; UIV = 9.8%), *A. birta* (long-haired grass mouse) (UI = 15.8%; UII = 6.3%; UIII = 15.2%; UIV = 3.3%), *Chelemys macronyx* (Andean long-clawed mouse) (UI = 1.3%; UII = 0%; UIII = 4.2%; UIV = 4.9%) and *L. micropus* (southern pericote) (UI = 1.3%; UII = 0%; UIII = 1.4%; UIV = 1.6%) were the most representative taxa. The hystricognath rodents *Ctenomys* sp. (tuco-tuco)

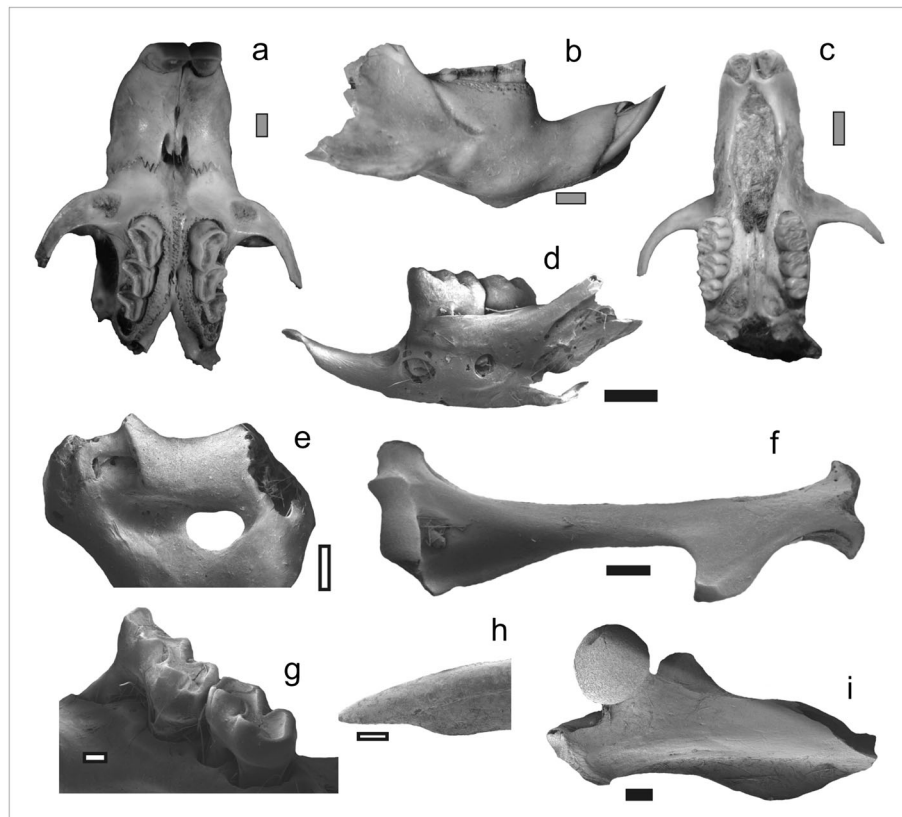


Figure 2. Taphonomic examples of *Bubo virginianus magellanicus*. (a) Skull of *Ctenomys* sp. (b) Mandible of *Ctenomys* sp. (c) Skull of *Euneomys chinilloides*. (d) Mandible of *Abrothrix olivacea*. (e) Distal humerus of Sigmodontinae rodent. (f) Humerus of Sigmodontinae rodent. (g) Lower molars of *Abrothrix birta*. (h) Incisor of Sigmodontinae rodent. (i) Proximal femur of Sigmodontinae rodent. Grey scales = 2 mm, white scales = 200 µm, black scales = 1 mm.

Table 2. Percentage of fragmentation (PF) of cranial and postcranial elements evaluated from *Bubo virginianus magellanicus* and Laguna El Sosneado-3 archaeological site samples

	PF <i>B. v. magellanicus</i>	PF Unit 1	PF Unit 2	PF Unit 3	PF Unit 4
Maxillae	44.94	100	100	100	97.06
Mandibles	52.70	86.27	88.61	89.89	85.71
Humeri	18.86	50.42	46.67	39.05	50
Femora	22.44	50.67	50	46.67	56.72
Scapulae	87.18	94.87	97.22	100	100
Ulnae	18.79	55.56	53.45	58.43	41.86
Radial	6.29	18	22.22	31.25	47.50
Pelves	19.88	100	98.44	100	93.18
Tibiae	17.91	69.75	52.43	57.26	57.69
Incisors	6.78	27.27	45.45	50.77	70.83
Molars	1.72	22.50	26.92	26.42	22.92
Metapodials	2.22	0	0	0	0
Vertebrae	1.24	9.09	4.83	7	6.08
Ribs	41.77	81.82	60	71.70	60.53

(UI = 10.6%; UII = 7.8%; UIII = 5.6%; UIV = 6.7%), whose body mass is over 150 g, were less representative.

The average relative abundance and results obtained from the evaluated indexes are present in Table 1.

More than 40% of remains were fractured before their burial, owing to the fact that there was no evidence of trampling marks in the entire sequence. Most of the broken skeletal elements presented sharp edges and rough surfaces (UI = 90.6%; UII = 91.7%; UIII = 96.6%; UIV = 97.4.5%), and only a few of them had rounded edges and smooth surfaces.

The percentage of fragmentation of all skeletal elements was evaluated; the results are shown in Table 2.

Only one skull was found complete (in UIV). Most skull fragments corresponded to maxilla without zygomatic arches (Figure 3). The losses of teeth were moderate in all the units.

A few complete mandibles were recorded in all the units. Some of the fractured mandibles possessed the ascending ramus, and others presented the inferior edge of mandibular ramus as broken. In all the units, moderate proportions of molars were lost from the mandibles,

Table 3. Percentage of breakage of postcranial elements in *Bubo virginianus magellanicus* and Laguna El Sosneado-3 archaeological site samples

	% Femur	% Humerus	% Tibia	% Ulna
<i>B. v. magellanicus</i>				
Complete	77.6	81.1	82.1	81.2
Proximal	15.6	2.9	10.4	10.1
Distal	3.4	13.7	5	8.7
Shaft	3.4	2.3	2.5	0
Unit 1				
Complete	44.6	48	28.3	38.9
Proximal	44.6	13	22.5	59.7
Distal	8.4	37.4	41.1	0
Shaft	2.4	1.6	8.1	1.4
Unit 2				
Complete	48.4	59.6	47.8	46.6
Proximal	48.4	1.1	14.2	50
Distal	1.1	38.3	28.3	0
Shaft	2.1	1.1	9.7	3.4
Unit 3				
Complete	47.5	56.6	38.7	41.6
Proximal	37.6	0.9	15.3	58.4
Distal	3.9	36.3	38.7	0
Shaft	10.9	6.2	7.3	0
Unit 4				
Complete	42	46.6	38.4	56.8
Proximal	47.8	6.8	16.3	40.9
Distal	4.3	43.8	33.7	0
Shaft	5.8	2.7	11.6	2.3

Bubo virginianus magellanicus (Strigidae) as Rodent Bone Accumulator

Table 4. Percentages of digestion in postcranial (proximal femur and distal humerus) and teeth (incisors and molars) evaluated from *Bubo virginianus magellanicus* and Laguna El Sosneado-3 archaeological site samples

	% Absent	% Light	% Moderate	% Heavy	% Extreme
<i>B. v. magellanicus</i>					
Femur	41.2	23.6	15.7	9.9	8.9
Humerus	37.6	23	27.3	7.9	4.2
Incisor <i>in situ</i>	19.2	39.2	37.2	3.2	1.2
Isolated incisor	0	1.8	46.4	44.6	7.1
Molar <i>in situ</i>	62	31	6.4	0.6	0
Isolated molar	33.3	55	10	1.7	0
Unit 1					
Femur	58	32.6	8.1	1.3	0
Humerus	70.5	28.6	0.9	0	0
Incisor <i>in situ</i>	78.6	21.4	0	0	0
Isolated incisor	72.7	24	2	1.3	0
Molar <i>in situ</i>	94.3	5.7	0	0	0
Isolated molar	72.5	27.5	0	0	0
Unit 2					
Femur	44.6	33.7	19.5	2.2	0
Humerus	81.5	16.3	2.2	0	0
Incisor <i>in situ</i>	72.1	27.9	0	0	0
Isolated incisor	62.5	35.2	2.3	0	0
Molar <i>in situ</i>	80.8	17.9	0.4	0.9	0
Isolated molar	65.4	34.6	0	0	0
Unit 3					
Femur	50	34.9	11.6	3.5	0
Humerus	67.6	29.5	2.9	0	0
Incisor <i>in situ</i>	83.6	14.6	1.8	0	0
Isolated incisor	72.3	18.5	9.2	0	0
Molar <i>in situ</i>	84.9	14.7	0.4	0	0
Isolated molar	75.5	24.5	0	0	0
Unit 4					
Femur	51.6	41.9	6.5	0	0
Humerus	83.3	16.7	0	0	0
Incisor <i>in situ</i>	69.6	30.4	0	0	0
Isolated incisor	81.9	18.1	0	0	0
Molar <i>in situ</i>	87.4	12.6	0	0	0
Isolated molar	81.3	18.7	0	0	0

whereas it was moderate for incisors in UI, UII and UIII and light in UIV. Teeth found *in situ* showed minor breakage extent than those found isolated.

Breakage results of postcranial elements were similar in all the units (Table 3).

In the fossil sample, more than 73% of skeletal elements and teeth that have been evaluated considering the degree of digestion have no evidence of this process (Figure 3 and Table 4). In some incisors, the corrosion was concentrated on the edges, and some cusps of molars showed a more rounded shape, while in some incisors, the corrosion was extended over a larger surface, making it wavy, and some cusps of molars presented light pitting in the enamel. Some humeri and femora showed light pitting, whereas some others showed abraded or polished cortical surfaces. In all the units, isolated teeth were more damaged than those found *in situ* (Table 4), owing to the larger surface exposed to digestive acids (Andrews, 1990).

Discussion

Comparison between modern samples of Bubo species

In the *B. v. magellanicus* sample, the average relative abundance was low (47.8%). The anatomical representation results in a typical 'owl' pattern (Andrews, 1990). It showed differences with the curves of other *Bubo* evaluated by Andrews (1990), but they were the same as regards the representativity of maxillae, mandibles, humeri and femora and the low representativity of isolated teeth (Figure 4a). On the other hand, there were coincidences in anatomical representation with samples of *B. v. nacurutu* evaluated by Gómez (2005). Comparison of representativity of each element mainly showed similarities with the sample from Catamarca (Figure 4b). Anyway, the results came from the evaluation of very few pellets, and the differences may be due to the sample size.

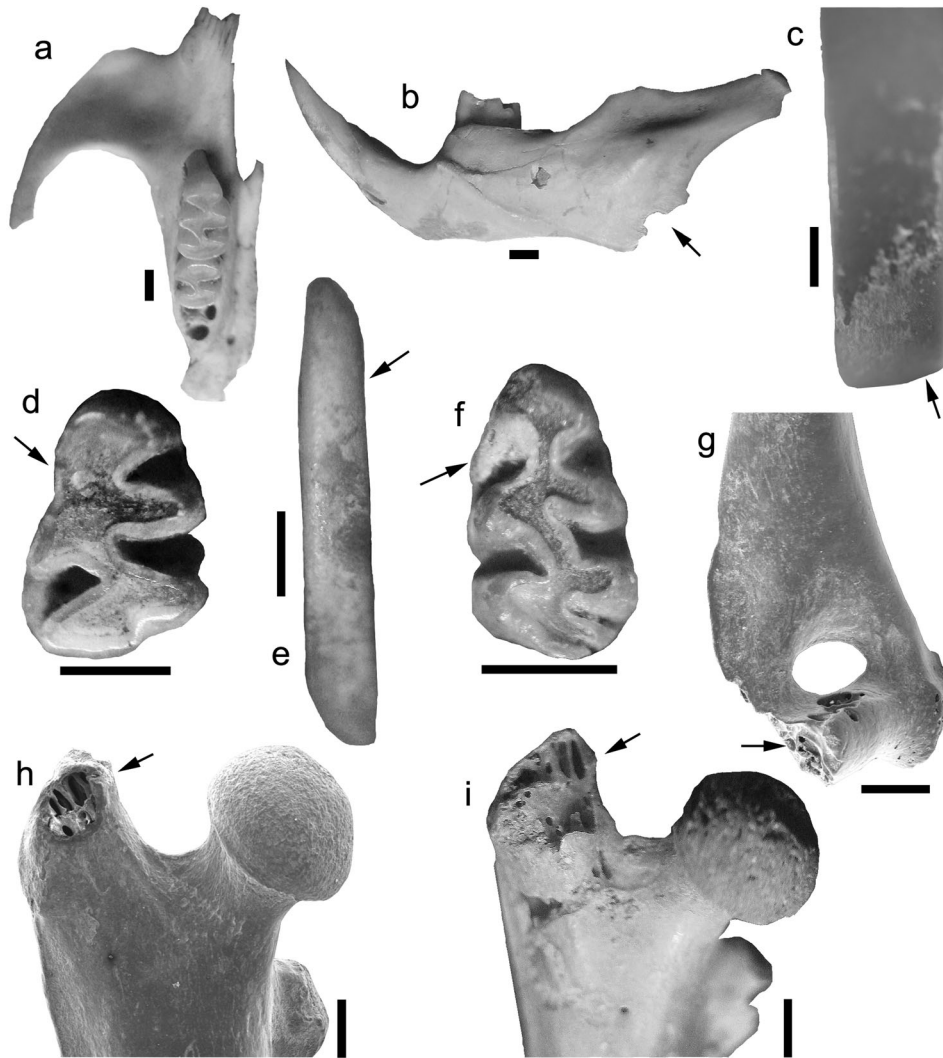


Figure 3. Taphonomic examples of different units of Laguna El Sosneado-3 archaeological site. (a) Maxilla of *Phyllotis xanthopygus* (UIV). (b) Mandible of *P. xanthopygus* (UIII). (c) Incisor of *Ctenomys* sp. with light alteration (UI). (d) Upper first molar of *P. xanthopygus* with light alteration (UIII). (e) Incisor of Sigmodontinae with moderate alteration (UIII). (f) Lower first molar of *Eligmodontia* sp. with moderate alteration (UIII). (g) Humerus of Sigmodontinae with light alteration (UI). (h) Femur of Sigmodontinae with light alteration (UI, photo taken from Otaola et al., 2014: Figure 2a). (i) Femur of Sigmodontinae with moderate alteration (UIII). Scales 1 mm.

In the *B. v. magellanicus* sample, the indexes that assessed the relationship between cranial and postcranial elements (Table 1) gave the expected results for a Strigiformes because they indicated a good representation of both types of skeletal elements and a little deficiency of postcranial elements. Accordingly, Andrews (1990) and Gómez (2005) gave similar proportions in *Bubo bubo*, *Bubo lacteus* and *B. v. nacurutu* samples (Table 5), and they attributed these deficiencies to the differential destruction of these elements.

The preservation of molars in their alveoli was high (81.59%). Andrews (1990) and Gómez (2007) observed a similar proportion in Strigiformes. When these birds swallowed a whole prey, they produced low or

moderate levels of breakage in bone remains, compared with other predators such as Falconiformes, Accipitriformes, carnivorous mammals and even humans that dismembered their prey (e.g. Andrews, 1990; Dewar & Jerardino, 2007). In fact, the *B. v. magellanicus* sample showed moderate values of breakage (Tables 2 and 3). Specifically, the evaluation of the percentage of fragmentation showed that the scapulae, ribs, mandibles and maxillae were the skeletal elements with the highest proportion of breakage. No skull was intact, the maxillae being the most common elements, indicating the loss of the entire braincase. Because of these features, *B. v. magellanicus* would be among the predators that produce moderate damage, in this sense being similar to *Bubo*

Bubo virginianus magellanicus (Strigidae) as Rodent Bone Accumulator

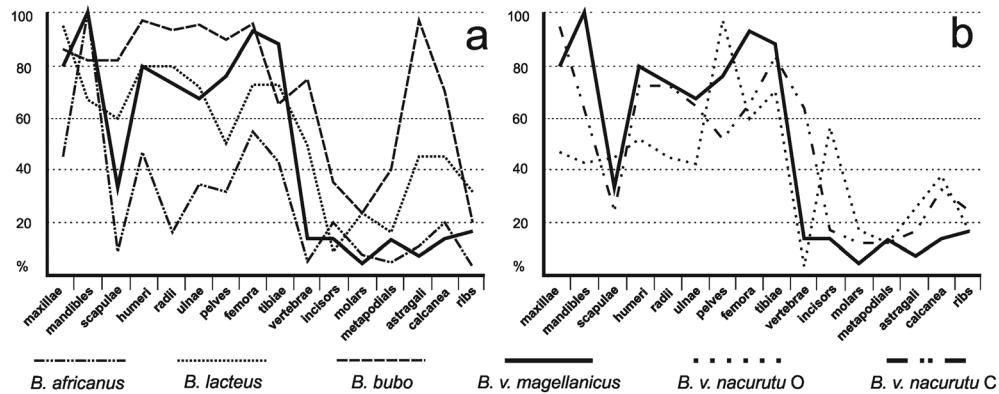


Figure 4. Relative abundance of skeletal elements identified in the sample of *Bubo virginianus magellanicus* compared with (a) data from *Bubo africanus*, *Bubo bubo* and *Bubo lacteus* and (b) data from *Bubo virginianus nacurutu* from Olavarría (O) and Catamarca (C).

africanus (Andrews, 1990). Concerning the completeness of mandibles, the preservation of complete mandibles was high (47.3%). These percentages, similar to those obtained for *B. lacteus* and *B. bubo* (Andrews, 1990), showed a very good preservation of these elements. Hence, *B. v. magellanicus* is among the predators that caused little modification on the mandibles of their prey.

Long bones were mostly complete (83%), typical of assemblages produced by Strigiformes (Andrews, 1990), and it indicated that *B. v. magellanicus* caused little breakage in the postcranial elements. Among the broken elements, the proximal portions of femora, tibiae and ulnae, and distal humeri were dominant. As in

many micromammal predators and humans (Andrews, 1990; Dewar & Jerardino, 2007), the analysed sample showed a better preservation of the proximal elements of the limbs, perhaps owing to the greater fragility of the distal elements (Andrews, 1990). Gómez (2005) also pointed out a little loss of distal elements in *B. v. nacurutu* samples, but he also found a high percentage of whole bones. It should be emphasized that, in these cases (Mendoza and those studied by Gómez), the materials were still in the pellets.

Strigiformes birds produce micromammal assemblages with light to moderate alteration by digestive corrosion (e.g. Andrews, 1990; Gómez, 2005, 2007;

Table 5. Averages of different analysed variables of *Bubo virginianus magellanicus* compared with other *Bubo* and *Tyto alba* samples

	<i>B. v. magellanicus</i> (this study)	<i>Bubo bubo</i> (Andrews, 1990)	<i>Bubo lacteus</i> (Andrews, 1990)	<i>Bubo africanus</i> (Andrews, 1990)	<i>Bubo virginianus</i> <i>nacurutu</i> (Gómez, 2005)	<i>Tyto alba</i> (Andrews, 1990)
Average of relative abundance	47.8	41	58.6	27	58.3	43.8
pc/c index	310.6	234	172	172	214.3	251
(f + h)/(md + mx) index	95	111	80	74	103.4	93
Distal element loss	94.7	75	100	52	109.8	105
% Isolated incisors	110.4	102	65	90	88.9	56
% Isolated molar	25.7	70	61	34	41.8	96
% Digestion of incisors	82.3	48	25	57	32.5	5
% Digestion of molars	34.9	13.4	0.4	4.1	42.9	1.2
% Digestion of postcrania	76.9	34.6	6.2	25	35.1	11.1
% Breakage of crania	28	73	15	83	100	25
% Breakage of mandibles	52.7	62	16	93	64	22
% Breakage of postcrania	17.3	13	2.5	33.5	34.4	2.2
% Breakage of teeth	2.1	3.2	3	2	4.4	0
Category	2	2–3	1–2	2–3	2–3	1

Montalvo & Tejerina, 2009; Rudzik *et al.*, 2013). Among the analysed skeletal elements, 32.33% of them did not have any evidence of digestion, 28.93% had light digestion evidence, 23.83% had moderate digestion evidence, 11.33% had heavy digestion evidence and 3.58% had extreme digestion evidence. These percentages revealed that many remains had a light or moderate modification produced by digestive acids. Most molars (62%), femora (41.88%) and humeri (37.58%) showed no digestion evidence. Incisors showed differences in the percentages of digestion according to whether they were still in their alveoli (81%) or isolated (100%), the latter being much more affected by digestion. Some teeth had cracked dentine due to digestive effects. Molars of *Ctenomys* sp. showed no strong differences with those of sigmodontines in the digestion degree. In *Ctenomys* sp., the occlusal morphology with rounded edges and the presence of a smooth outer enamel layer, continuous and thick enough, might be decisive in how these molars were affected by digestion, or at least, it was not as evident even considering that these were hypsodont molars. The results yielded by this sample suggest that this predator should be placed in Category 2 of digestion, as it included skeletal elements with light to extreme modifications.

Table 5 summarizes the interpretations arising from the results. This allowed the allocation of *B. v. magellanicus* in the Category 2 of modification. The taphonomic analysis performed by Fernández *et al.* (2009) showed that it produced moderate modifications in bird assemblages (Category II, *sensu* Bochenski *et al.*, 1998). The species of *Bubo* studied by Andrews (1990) were placed in the Categories 1 and 2 (light and intermediate) of modification. However, Gómez (2005) placed *B. v. nacurutu* in Category 3, stating that the differences with other species of *Bubo* were mainly in the representative indexes.

Comparison between fossil and modern rodent accumulations

Bubo virginianus magellanicus is characterized by a diet based mainly on micromammals (e.g. Nabte *et al.*, 2006). Among the biases that it originates, an underrepresentation of strictly diurnal micromammals and large-sized ones (>150 g) stood out as well as a higher proportion of species occupying open habitats with high exposure (e.g. Pardiñas, 1999). Indeed, the pellets tested here contained bones of small vertebrates mostly with a body mass less than 80 g, except for the presence of some specimens of *Ctenomys* sp. By coincidence, microvertebrates found in the LS-3 archaeological site

presented almost the same taxonomic structure. The differences between the archaeological and modern samples are due to the anthropic impact (mostly of the exotic livestock) on the environments during the last ~200 years (Fernández, 2012, in press). In fact, recent disturbed areas favour the increase of opportunistic taxa such as *A. olivacea* and *Eligmodontia* sp. (Fernández, 2012, in press). Moreover, these features are important because they allow the separation of micromammal sets generated by *B. v. magellanicus* from those accumulated by humans, which are dominated by large-sized taxa, colonial, grouped or aggregated such as *Ctenomys* sp. (Pardiñas, 1999). On the other hand, *Tyto alba* (barn owl) also lives in caves and rocky shelters. It inhabits open environments and displays an opportunistic trophic behaviour. Finally, it feeds mostly on small mammals (e.g. Bellocoq, 2000, and references therein). Such features suggest the *T. alba*'s possible involvement in the origin of assemblages.

The average relative abundance was low in all the fossil units (average 17.5%); the results were significantly lower than those of the *Bubo* and *Tyto* samples. Some similarities in the curves of anatomical representativity of the elements recovered from current samples and LS-3 are observed. Values of over 70% were observed (maxillae, mandibles, humeri, pelves, femora and tibiae; Figure 5). Mandibles, tibiae and humeri were the element with better representation in LS-3. Vertebrae, isolated incisors and molars, elements of autopodium and ribs were the poorly represented ones in both the fossil and modern samples.

The indexes evaluated on fossil units indicated an overall better preservation of postcranial elements with the exception of UI that showed a loss of distal elements. As regards *Bubo* and *Tyto* samples, there was only a slight loss of postcranial elements. *Tyto alba* samples had similar numbers of postcranial and cranial elements. Molar retention in all the archaeological units was better too, as in *Bubo* and *Tyto* samples.

Skeletal elements and teeth from archaeological samples had fractures that could be related to predatory activity. Both in these samples and in the current one, the highest percentage of breakage was in cranial elements and scapulae, with a different proportion of damage. Regarding *T. alba*, skulls, mandibles and other skeletal elements were scarcely damaged. All the metapodials were complete in the archaeological samples, and very few of them were broken in the *Bubo* sample. Vertebrae were more complete in the *Bubo* sample. Ribs, radii and pelves presented higher levels of breakage in LS-3. Finally, in all cases, femora and ulnae showed higher proportions of proximal

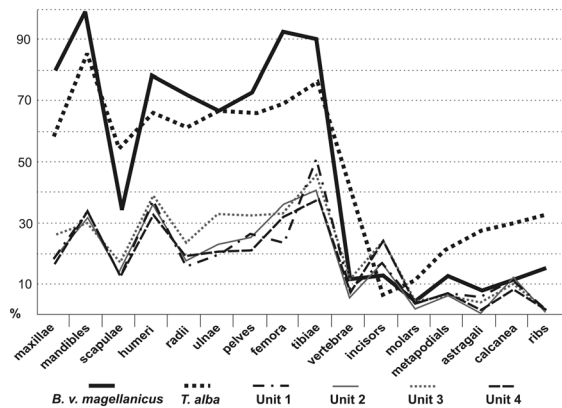


Figure 5. Relative abundance of skeletal elements identified in the sample of *Bubo virginianus magellanicus* compared with *Tyto alba* (average, Andrews, 1990) and Laguna El Sosneado-3 samples.

segments, whereas distal segments were predominant in the humeri and tibiae.

In LS-3, the anatomical representation, indexes and degree of breakage features might be attributed to postdepositional processes (Otaola *et al.*, 2014) that could produce breakage or a direct loss of skeletal elements. Initial breakage and skeletal element distributions have been obscured by these processes. For these reasons, the best diagnostic evidence of the mode of accumulation was the effects of digestion (Andrews, 1990; Demirel *et al.*, 2011).

As regards the *Bubo* sample, 32% of the skeletal elements evaluated had no digestion evidence, and 29% of them showed a light degree of digestion. Considering the fossil sample, the light corrosion traces were less frequent (UI = 23%; UII = 28%; UIII = 23%; UIV = 23%). Only UIII showed similar values. The *Bubo* sample had 24% of remains categorized as moderate, and the fossil samples had between 1% and 4% of such remains, with a high average in UII and UIII. Heavy and extreme modifications were higher in the *Bubo* sample (more than 11% and 3%, respectively). Concerning LS-3, remains belonging to these categories of modification were practically absent.

Tyto alba was taphonomically located in Category 1 (e.g. Andrews, 1990). Coincidentally, considering UI and UIV, the absence of remains with extreme modifications and less percentage of remains with heavy modifications allowed suggesting that this strigiform might have probably participated in the accumulations of these units, whereas UII and UIII had a higher proportion of remains with moderate and heavy modifications. As a consequence of this, there was a suggestion to place them in Category 2 and that these units and *B. v. magellanicus* might have been their accumulator.

Fernández (2012) and Otaola *et al.* (2014) enunciated the hypothesis about the participation of *B. v. magellanicus* in the micromammal accumulations from UII and UIII of LS-3, based on the taphonomic comparison with other subspecies that inhabited the plains (*B. v. nacurutu*). As regards UI and UIV, these authors suggested the action of *T. alba* as a micromammal accumulator, with a more suitable current framework. Therefore, according to the results presented here, these hypotheses might be accepted.

Conclusions

According to the main taphonomic variables, *B. v. magellanicus* may be placed in the Category 2 (intermediate) of modification of prey bones based on the scheme proposed by Andrews (1990). This location indicates that it affects the prey bones a bit more than most of the species of *Bubo*, which produce a degree of taphonomical modification between Categories 1 and 2, but less than the other subspecies that inhabit Argentina.

In sum, *B. v. magellanicus* can generate micromammal assemblages on rock shelters associated to archaeological sites, mainly formed by sigmodontine rodents; good representation of maxillae, mandibles, humeri, femora and low representativity of isolated teeth; similar proportions of cranial and postcranial elements; better preservation of proximal elements; moderate values of breakage; and intermediate values of digestive corrosion.

Besides, the micromammal assemblages generated by *B. v. magellanicus* differ clearly from those of other predators (Falconiformes and Accipitriformes birds and carnivorous mammals). In this sense, its differentiation from mammal assemblages accumulated by human activity could be proved; this is important to solve the problems of equifinality common in zooarchaeological contexts.

The comparison of both archaeological and modern micromammalian samples allows us to indicate that the skeletal element assemblages recovered throughout the LS-3 sequence would have had its origin in the predatory activity of strigiform birds. In fact, the taphonomical evidence of a light modification (Category 1) in UI and UIV points out that *T. alba* is the main species involved in the micromammalian formation of these parts of the sequence, whereas taphonomical evidence on assemblages recovered from UII and UIII suggests the action of a strigiform with a major category of modification as *B. v. magellanicus*.

This study will contribute to the understanding of the taphonomy of South American nocturnal raptors and may be extrapolated to create models to interpret small mammal remains in archaeological and palaeontological faunal assemblages produced by different predators, including humans.

Acknowledgements

This work has been funded by Project 210 of the Facultad de Ciencias Exactas y Naturales, UNLPam, and Project 11/N769 of the Facultad de Ciencias Naturales y Museo, UNLP. Special thanks are given to C. Deschamps and A. Martinez for the English translation and to Germán Moreira and 'Grupo de Arqueología de Mendoza' for field work support. Special thanks are extended to anonymous reviewers and to the editor N. Sykes, whose comments and suggestions have greatly improved this paper.

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