Small mammal remains recovered from two archaeological sites in the middle and lower Negro River valley (Late Holocene, Argentina): Taphonomic issues and paleoenvironmental implications

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ABSTRACT

This paper presents the results of a taphonomic and paleoenvironmental analysis of small mammal remains recovered from the Negro Muerto and Angostura 1 archaeological sites. These sites (ca. 0.5 and 0.95 ka BP, respectively), are located in the middle and lower Negro River valley in northern Patagonia, Argentina. Based upon the presence of several types of evidence (cut marks, bone tools, and thermal alteration), it is proposed that *Holochilus brasiliensis* and cavies were acumulated by humans. At the Angostura 1 site, some remains also show evidence of having been generated by carnivores (digestion, breakage patterns, and relative skeletal element abundances). This indicates that carnivores (e.g., *Puma concolor*) could have contributed to the formation of the small mammal assemblages. Other small mammal species recovered at both sites (e.g., *Galea leucoblephara*, *Microcavia australis*, *Akodon molinae*, and *Graomys griseoflavus*) suggest semi-desert environmental conditions, similar to those found today. The presence of *Reithrodon auritus* and *Oligoryzomys* sp. indicate the development of open herbaceous steppe environments in proximity to bodies of water. However, the discovery of *H. brasiliensis* at both sites, an orizomyine of amphibious habitats and subtropical origin, and which is now absent in the area, suggests warmer and wetter conditions during this period.

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1. Introduction

Until recently, the study of small mammals (<1 kg) has been somewhat marginalized in zooarchaeological studies in Argentina. This might be due to several reasons: (a) the difficulties associated with taxonomic determinations, (b) difficulties in recovering this type of remains during fieldwork, and (c) the lack of a coherent theoretical-methodological model to apply. In the last two decades, this situation has changed, inspired by research developed in other parts of the world, where theoretical-methodological issues have been addressed in the study of small mammals (see Hoffman, 1988; Andrews, 1990; Fernández-Jalvo and Andrews, 1992; Denys et al., 1995, 1997; Stahl, 1996). Following upon these advances, recent research in Argentina has focused on taphonomic (e.g., Pardiñas, 1999a, b; Quintana et al., 2002; Santiago, 2004; Acosta and Pafundi, 2005; Quintana, 2005; Gómez and Kaufmann, 2007; Montalvo et al., 2007, 2008; Fernández et al., 2009), paleoenvironmental (e.g., Pardiñas, 1999b; Teta et al., 2005a, b; Fernández et al., 2009), and chorological approaches (e.g., Pardiñas, 1999b; Teta et al., 2005b; Teta and Pardiñas, 2006). Despite this increasing development of small mammal studies in Argentina, in northeastern Patagonia only a few analyses of microvertebrates involving taphonomic and paleoenvironmental perspectives have been carried out (Prates, 2008; Stoessel et al., 2008). In this context, Prates (2008) presented a preliminary study of the microvertebrates from the Angostura 1 (abbreviated below as A1) and Negro Muerto (abbreviated below as NM) archaeological sites. These sites are located in the Negro River valley and were occupied during the Late Holocene.

The main subject of this paper is an exhaustive analysis of the taphonomic and paleoenvironmental aspects of the small

mammal assemblages recovered at the A1 site, which expands upon the earlier preliminary study conducted by one of the present authors (Prates, 2008). Due the scarce remains of the NM site, the previous taphonomic analysis made in this site are used as complementary data (Prates, 2008). Modern samples of rodents obtained from areas near the sites were also analyzed, in order to compare them with the archaeological samples. This provides

data with which to build a more extensive paleoenvironmental model of the area.

2. Regional setting

The A1 archaeological site is located in a narrow section of the lower Negro River valley, 155 km from the river's mouth at the
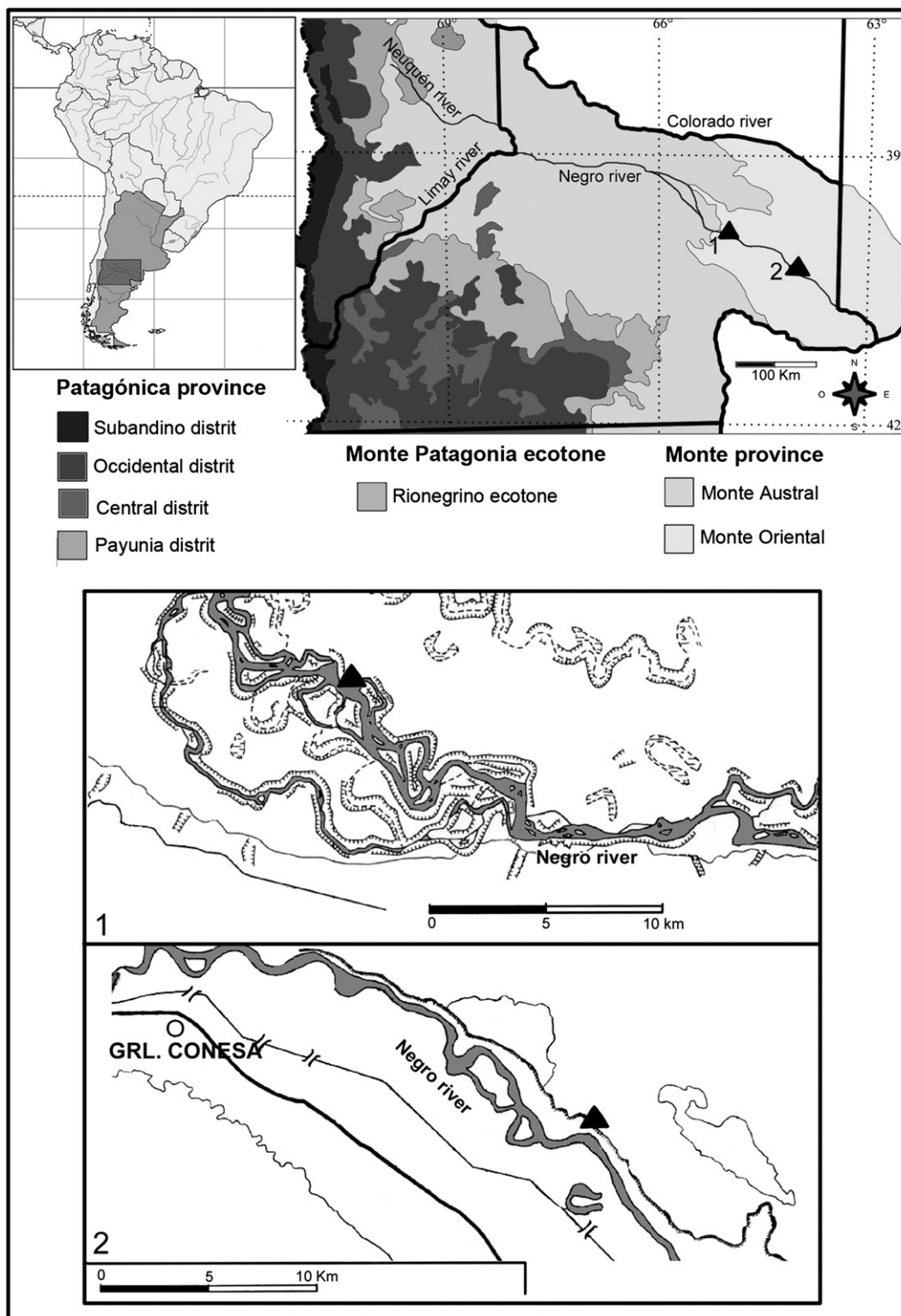

Fig. 1. Map showing the study area and the archaeological sites analyzed. 1, Negro Muerto (NM) and 2, Angostura 1 (A1). Phytogeography follows León et al. (1998).

Atlantic Ocean, and 20 km southeast of the town of General Conesa (40°10′S, 64°11′W). The site lies 60 m from the present-day river bank. The NM site is located in the middle Negro River valley, 70 km southeast of the town of Choele Choel and 265 km to the northwest of the mouth of the river, at 39°50′S, 65°17′W (Prates, 2008) (Fig. 1).

The modern climate at the latitude of the middle valley is mesothermal arid (Thornthwaite, 1948), and mesothermal semi-arid in the lower valley. This area is located in the climatic region known as the South American Arid Diagonal, which covers a large part of the subcontinent, from northern Peru, along the Andes to the south of Neuquén, and continuing across Patagonia to near the mouth of the Chubut River (Bruniard, 1982). Both the middle and lower Negro River valley have an average annual temperature of 14.2 °C, and annual precipitation gradually increases from ca. 300 mm in Choele Choel, to ca. 400 mm along the Colorado River, and to ca. 500 mm at this river's mouth. The amount and distribution of precipitation varies according to the predominance of west winds and the influence of Atlantic air masses (Páez et al., 2001).

Both sites are located in the Monte phytogeographic province, Monte Oriental district (*sensu* León et al., 1998), with the annual precipitation at both sites being ca. 250 mm, and with greater amounts of vegetation cover than the typical Monte Austral (50–80%). An almost arboreal zone also exists, with abundant isolated groves of *Geophroea decorticans* and *Prosopis flexuosa*. The steppe is also characterized by the presence of a shrub layer between 1.5 m and 3 m in height (*Larrea divaricata*, *Condalia microphyla*, and *Prosopis alpataco*), and contains a generally sparse herbaceous layer (León et al., 1998).

From the zoogeographic point of view, the area makes up part of the Patagónico dominion (Ringuelet, 1961), and lies on the ecotone with the Central dominion. Some of the main species present include *Lama guanicoe* (guanaco), *Pseudalopex griseus* (gray fox), *Pseudalopex culpaeus* (red fox), *Puma concolor* (cougar), *Lyncodon patagonicus* (small ferret), *Zaedyus pichiy* (pichi), *Chaetophractus villosus* (larger hairy armadillo), *Dolichotis patagonum* (mara), and *Microcavia australis* (small cuis). Among the area's birds are *Pterocnemia pennata* (american ostrich), *Eudromia elegans* (elegant crested tinamou), and *Cyanoliseus patagonus* (burrowing parrot).

The middle Negro River valley is located between the Ventania mountain range in the southeastern Pampas and the Somuncura massif in northern Patagonia. This area is within the Colorado Valley geological province (La Cuenca del Colorado), which follows an extensive west-northeast fault line (Ramos, 1999), and is part of the Chacobonaerense Plain (Luchsinger, 2006). The Negro River valley is highly varied and the alluvial plains are very dynamic geoforms, exposed to continuous erosional and depositional processes (Brown, 1997; Waters, 1992). However, some areas may also have been established as the result of changes in ground level and the associated terrace formation (Huckleberry, 2001).

3. Materials and methods

A1 is an open-air archaeological site. Excavations took place in an area adjacent to an erosional bank, where the highest concentrations of archaeological materials were exposed in the profile. The dimensions of the excavated area were 5×3 m (15 m^2). A1 is a short term campsite where multiples activities were performed. The component which the micro-mammals remains comes from has no evidence of any incorporation of modern materials from upper levels nor evidence of pedogenesis (Prates, 2008). Other types of archaeological materials were also recovered, including lithic artifacts, plant remains, pottery sherds, and bones from large- and medium-sized mammals. *The geomorphologic and sedimentologic context shows that, after their acumulation, the archaeological materials were quickly covered by eolian limo-sandy sediments, which*

Table 1
Taxonomic composition of the small mammal sample from the A1 archaeological site (expressed as NISP, MNE, and MNI).

	NISP	%	MNE	%	MNI	%
Mammalia indet.	467	32.5	382	30.7	14	5.8
Rodentia indet.	122	8.5	87	7	14	5.8
Caviidae indet.	343	23.9	301	24.2	54	22.6
Galea leucoblephara	48	3.3	42	3.4	8	3.3
Microcavia australis	74	5.2	71	5.7	25	10.5
Ctenomyidae						
Ctenomys sp.	121	8.4	111	8.9	76	31.8
Cricetidae indet.	54	3.8	51	4.1	11	4.6
Akodon molinae	6	0.4	6	0.5	3	1.3
Akodon sp.	3	0.2	3	0.2	2	0.8
Holochilus brasiliensis	192	13.4	183	14.7	28	11.7
Oligoryzomys sp.	1	0.1	1	0.1	1	0.4
Graomys griseoflavus	2	0.1	2	0.2	1	0.4
Reithrodon auritus	2	0.1	2	0.2	2	0.8
Total	1435		1242		239	

allowed a high integrity and preservation of the site. A sample of 1435 small mammals remains were recovered (Table 1), at depths between 135 and 175 cm. The remains analyzed in this paper were associated with the stratigraphic layer dated to 938 ± 45 ^{14}C BP (sample #AA 2551).

NM is also an open-air site, located adjacent to an old meander scar as supported by the stratigraphic evidence. It appears that this original channel meander eroded into part of the sandy eolian mantle which is commonly found in the Middle Río Negro Valley. Based on the stratigraphic position of this archaeological site, the NM site is located close to the riverbanks of this old meander and was eventually buried by alluvial overbank sediments from the river. Once abandoned, this site was fully buried by overbank sediments until the meander was abandoned and alluvial deposition ceased.

A sample of 98 small mammals remains were recovered from between 50 and 80 cm in depth, and unfortunately were not sufficiently abundant to allow a detailed taphonomic analysis to be conducted (Table 2). The excavation area was 10 m^2. As at the A1 site, other types of archaeological materials were recovered, such as fresh-water mollusk shells, egg shell fragments, pottery sherds, lithics, and bone remains from large- and medium-sized mammals. Two radiocarbon samples from the NM site were dated at 483 ± 46 BP (sample #AA62795) and 398 ± 43 BP (sample #AA62794).

Remains of bones and teeth from both archaeological sites were recovered with a 2.5 mm screen mesh size, and examined with a binocular loop, and in some cases photographs were taken using scanning electron microscopy (SEM). The taphonomic studies

Table 2
Taxonomic composition of the small mammal sample from the NM archaeological site (expressed as NISP, MNE, and MNI).

	NISP	%	MNE	%	MNI	%
Rodentia						
Caviidae indet.	51	52	51	52	5	20.8
Galea leucoblephara	4	4.1	4	4.1	2	8.3
Microcavia australis	6	6.1	6	6.1	3	12.5
Ctenomyidae						
Ctenomys sp.	11	11.2	11	11.2	2	8.3
Cricetidae						
Akodon sp.	2	2	2	2	2	8.4
Holochilus brasiliensis	23	23.5	23	23.5	9	37.5
Eligmodontia sp.	1	1	1	1	1	4.2
Total	98		98		24	

followed the methodology used by Andrews (1990) and Fernández-Jalvo and Andrews (1992). The relative abundances of skeletal elements were evaluated with the representation of each element in the sample calculated (MNE_i), based upon the expected number of each skeletal element in the individual (E_i), and the minimum number of individuals (MNI), using the formula: MNE_i/ $(E_i \times MNI) \times 100$. In order to evaluate the relationships between cranial and post-cranial elements, two indices were calculated: $[(femur + tibia + humerus + radius + ulna) \times 16/(mandible + maxilla + molars) \times 10] \times 100$, and $[(humerus + femur) / (mandible + maxilla)] \times 100$. In order to observe the relationships between distal and proximal elements of the limbs, the following
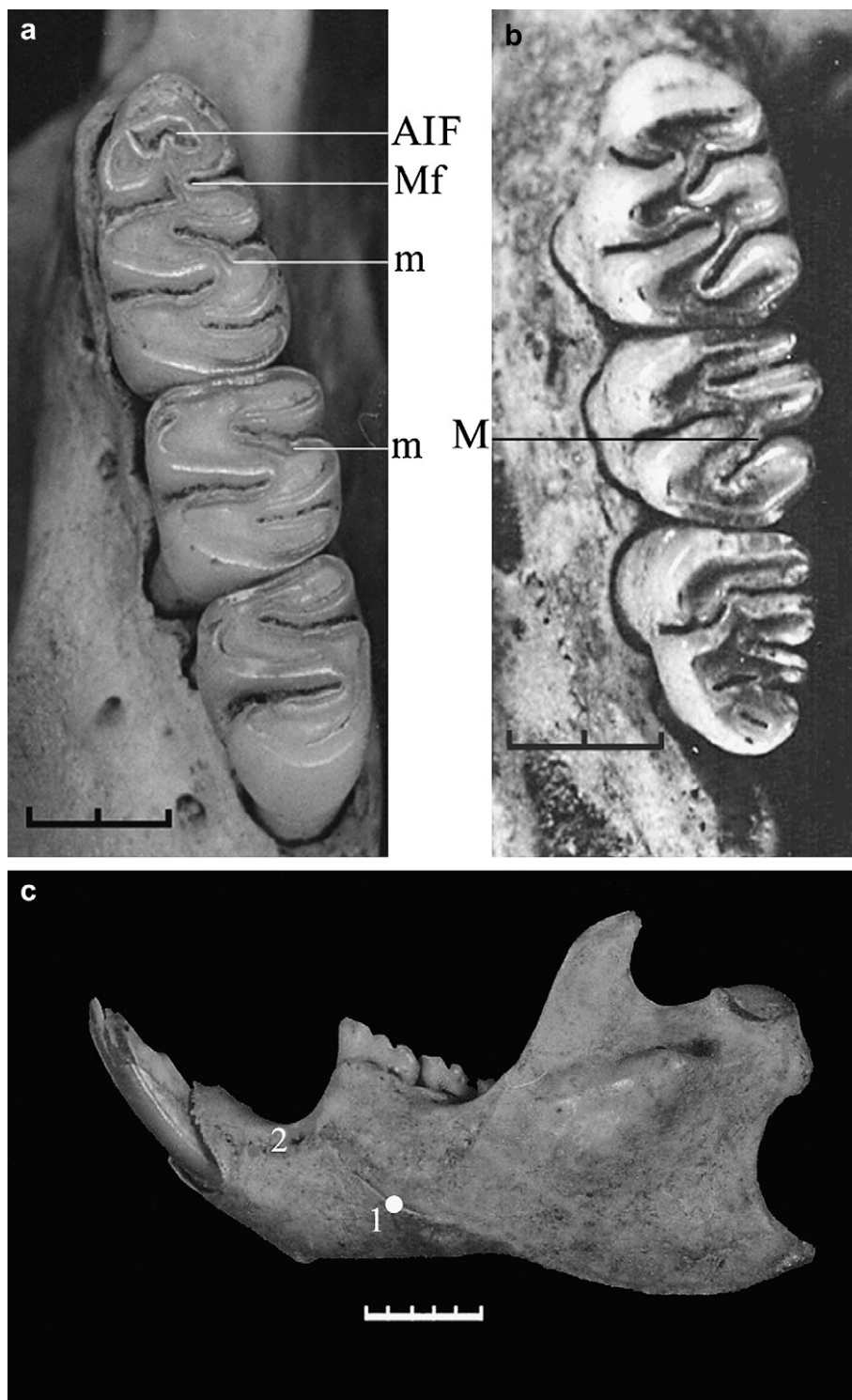
Fig. 2. Examples of *Holochilus brasiliensis* remains recovered at the A1 site. (A) (MLP 97-XI-1-2) series of lower left teeth, scale = 2 mm. (B) (MLP 97-XI-1-1) series of upper left teeth, scale = 2 mm. (C) (MLP 97-XI-1-2) labial view of the left mandible, scale = 5 mm. AIF, antero-internal fossetid; Mf, metaflexid; m, mesolophid; M, mesoloph (Scale = 2 mm). 1, Point of intersection of the upper and lower rami of the masseteric crest; 2, mentonian foramen.

index was calculated: [(tibia + radius)/(femur + humerus)] × 100. Next, two more indices were calculated to evaluate the proportions of individual teeth [(premaxillary alveoli + mandibular alveoli)/(incisors)] × 100, and [(maxillary alveoli + mandibular alveoli)/(molars)] × 100.

Taxonomic determinations for the small mammals were performed using cranial and dental remains, by comparison with reference materials from the collections of the Museo de La Plata, as well as with bibliographic sources. The specimens of *Holochilus brasiliensis* were identified using the following combination of characteristics: mandible with robust horizontal ramus and well-developed mentonian process; well-marked upper and lower masseteric crests that are joined and form a single rim at the top of the posterior root of the m1 and below the mentonian foramen; upper and lower molars with mesoloph/id present but poorly developed; rounded labial and lingual borders of the lophs/lophids; large antero-interna fossetids centrally located in the procingula of the m1; protocones and hypocones with unequal areas of almost triangular shape in the m1; well-developed met-aflexid that reaches the middle line in the m2; sub-quadrangular m2 in occlusal view, and sigmoidal m3 (see e.g., Hershkovitz, 1955; Massoia, 1976; Voglino et al., 2004; Teta et al., 2005a) (Fig. 2).

The taxonomic and systematic criteria adopted for analysis of the small mammals are those established in Pardiñas et al. (2003) and modified in later publications. The paleoenvironmental analysis is based upon the use of small mammals as indicators of environmental conditions, which allows paleoecological estimations to be made based upon the environmental requirements and known distributions of the various taxa (Pardiñas, 1999b; Andrews, 1995). For the study of the area's modern small mammals, 145 pellets of *Tyto alba* were disaggregated by wetting, then were submerged in warm water, and it was possible to identify a MNI of 299 (Table 3). The Shannon (*H′*) diversity index was used for the A1 archaeological sample and the modern sample, calculated on the basis of MNI using the EcoSim 700 program.

Table 3
Taxonomic composition of the modern small mammal assemblage from the *Tyto alba* samples (expressed as MNI and MNI%).

	MNI	%
Didelphimorphia		
Thylamys sp.	2	0.7
Rodentia		
Ctenomyidae		
Ctenomys sp.	44	14.7
Cricetidae		
Graomys griseoflavus	7	2.3
Calomys musculinus	86	28.8
Eligmodontia sp.	49	16.4
Oligoryzomys longicaudatus	38	12.7
Akodon azarae	33	11
Akodon molinae	9	3
Akodon iniscatus	1	0.3
Reithrodon auritus	2	0.7
Muridae		
Mus musculus	19	6.3
Rattus rattus	3	1
Lagomorpha		
Lepus europaeus	2	0.7
Chiroptera		
Myotis sp.	4	1.3
Total	299	

4. Results

4.1. Small mammal assemblages from the modern Tyto alba sample

As shown in Table 3, the small mammal assemblage from the modern sample recovered from *T. alba* pellets is made up primarily of sigmodontine rodents, with *Calomys musculinus* and *Eligmodontia* sp. being the most well-represented taxa, followed by low frequencies of *Oligoryzomys longicaudatus*, *Akodon azarae*, *Akodon molinae*, *Akodon iniscatus*, *Graomys griseoflavus,* and *Reithrodon auritus*. A single hystricognath rodent (*Ctenomys* sp.) was recorded, one chiropteran (*Myotis* sp.), and one marsupial marmosine (*Thylamys* sp.). Finally, the modern small mammal assemblage studied here also contained exotic species such as two murid rodents (*Mus musculus* and *Rattus rattus*), as well as a lagomorph (*Lepus europaeus*). The diversity index is 2.034.

The modern association shows a clear predominance of taxa characteristic of Monte desert (*C. musculinus*, *G. griseoflavus*, *A. molinae*, and *Thylamys* sp.; Pardiñas et al., 2003), with the addition of some Patagonian (*A. iniscatus*, *O. longicaudatus*, *Eligmodontia* sp., and *R. auritus*; Pardiñas et al., 2003) and Pampean elements (e.g., *A. azarae*; Pardiñas et al., 2004). Pardiñas et al. (2004) observed that *A. iniscatus* and *O. longicaudatus* have similar distributions in the southern Buenos Aires province, between the Colorado and Negro rivers. These authors also suggested that the effects of agro-ecosystems to the south of the Colorado River may have caused the expansion of *A. azarae* to the left bank of the Negro River, where they live partially in sympatry with *A. iniscatus*. Similarly, the high frequency of *C. musculinus* in this assemblage (Fig. 3) may indicate environmental degradation produced by farming activities. In a similar way, Pardiñas et al. (2000) related the predominance of *Calomys* sp. found in Lle Cul (Chubut River valley) to intense environmental transformations generated by the spread of agricultural systems during the last century. Udrizar Sauthier (2009) observed the same pattern in the eastern region of the Chubut River valley, based on a comparison of fossil and modern samples.

4.2. Small mammal assemblages from the archaeological samples (A1 and NM sites)

Data regarding the relative abundances of small mammals excavated at the A1 archaeological site are detailed in Table 1. In this assemblage, hystricognath rodents predominate (*Galea leucoblephara*, *M. australis*, and *Ctenomys* sp.). While most of the sigmodontine rodents show low frequencies (*Oligoryzomys* sp., *R. auritus*, *G. griseoflavus*, *A. molinae*, and *Akodon* sp.), *H. brasiliensis* occurs in higher amounts (Fig. 3). The diversity index is 1.714.

As with the A1 site, the small mammal assemblage from the NM site is comprised mainly of hystricognath rodents (*G. leucoblephara*, *M. australis*, and *Ctenomys* sp.) and the orizomyine *H. brasiliensis*. The remains of other sigmodontine rodents (*Akodon* sp. and *Eligmodontia* sp.) were scarce (Fig. 3 and Table 2).

4.3. Taphonomic analysis

4.3.1. A1 site

Of the analyzed remains, 24.5% showed signs of alteration by digestive action (see Table 4), which was classified as light, moderate, heavy, or extreme (*sensu* Andrews, 1990). For the proximal portions of the femurs and distal portions of the humeri, 52.9% showed some degree (light or moderate) of digestion. Many remains have an abraded or polished appearance, with the edges of fractures lightly rounded. In other cases, the remains possessed undulating diaphyses and strongly digested epiphyses (Fig. 4).
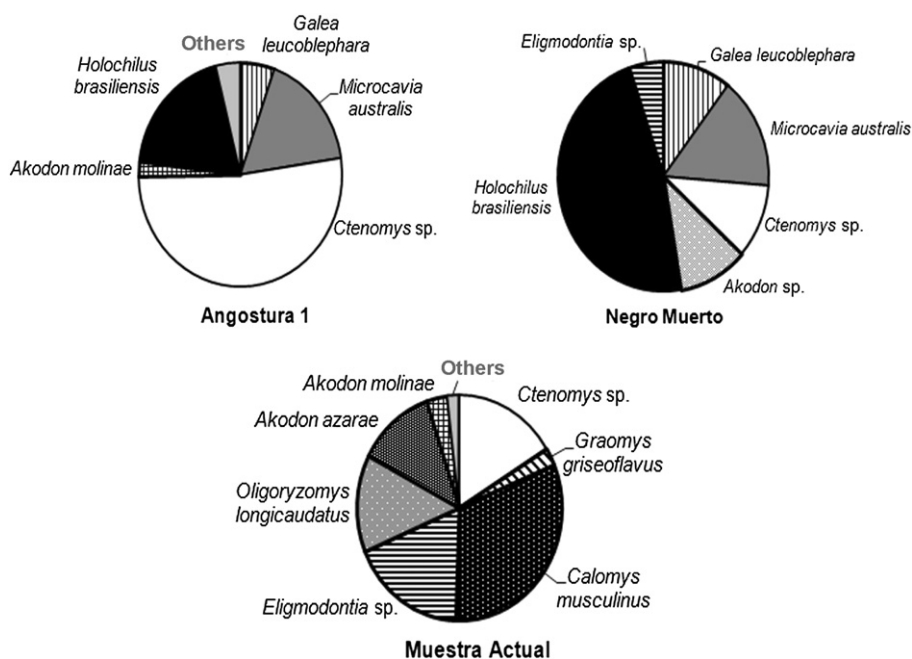
Fig. 3. Comparison of the relative abundances of native rodents (only for those taxa with MNI > 1 at the level of genus or species) in the archaeofaunal and modern samples.

Table 4
Representation of the various categories of digestive corrosion for the small mammal assemblage from the A1 archaeological site.

	Digestion classes *sensu* Andrews (1990)									
	Absent		Light		Moderate		Heavy		Extreme	
	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%
Digestion of teeth										
Incisors *in situ*	66	73.3	8	8.9	7	7.8	5	5.6	4	4.4
Isolated incisors	19	61.3	3	9.7	4	12.9	3	9.7	2	6.5
Incisors total	85	70.2	11	9.1	11	9.1	8	6.6	6	5
Molars *in situ*	293	86.4	19	5.6	13	3.8	10	2.9	4	1.2
Isolated molars	96	83.5	7	6.1	5	4.3	5	4.3	2	1.7
Molars total	389	85.7	26	5.7	18	4	15	3.3	6	1.3
Digestion in postcranials										
Proximal femur	28	42.2	25	37.9	10	15.2	3	4.5	0	0
Distal humerus	38	51.3	28	37.8	4	5.4	2	2.7	2	2.7

Fig. 4. Humerus showing heavy digestive corrosion on the distal epiphysis.

With the dental remains, 17.6% showed evidence of digestion. On some incisors the corrosion was concentrated on the edges. On others it was spread across most of the surface of tooth, making the surface rough and reducing the presence of the enamel to small isolated areas. Some cusps of molars showed a more rounded shape, while on others the enamel is thinned and degraded, so that it has disappeared across most of the tooth. Isolated incisors and molars were more affected than those found *in situ* (implanted), which suggests that individual teeth are more heavily exposed to digestive acids (Andrews, 1990). The average relative abundance of the sample was very low (9.8%), with the most represented elements being mandibles, maxillas, humeri, femurs, and tibias (Fig. 5 and Table 5).

Table 6 summarizes the presence of cranial, dental, and post-cranial breakage. Almost all of the crania were found fractured; most of them showing maxillas with the zygomatic arches fragmented or missing. Most of molars were lost from the maxillas, although a high frequency of incisors remained in the premaxillas. Few complete mandibles were found, with only a low proportion possessing the ascending ramus, and in more than half the inferior edge of the mandibular ramus was broken. A high percentage of molars and incisors had been lost from the mandibles.

The proportion of fractured molars and incisors was high, and in both cases the teeth found *in situ* showed more breakage than the isolated ones. The degree of fracturing in the post-cranial elements was very high, with only 6% of the humeri, ulnas, femurs, and tibias being complete. The femurs, tibias, and ulnas showed a higher proportion of proximal segments, but in the humeri distal segments were predominant. The rest of the elements were fractured (vertebrae, ribs, scapulae, radii, pelvi, calcanea, metapodia, and phalanges), with rounded edges and smooth surfaces.

The values obtained for the indices calculated are seen in Table 7. Those that evaluate the relations between post-cranial and cranial elements suggest better preservation of the latter. Also, the index that estimates the relationship between distal and proximal elements of the limbs indicates a loss of distal elements. The index that measures the relative proportion of isolated teeth shows that
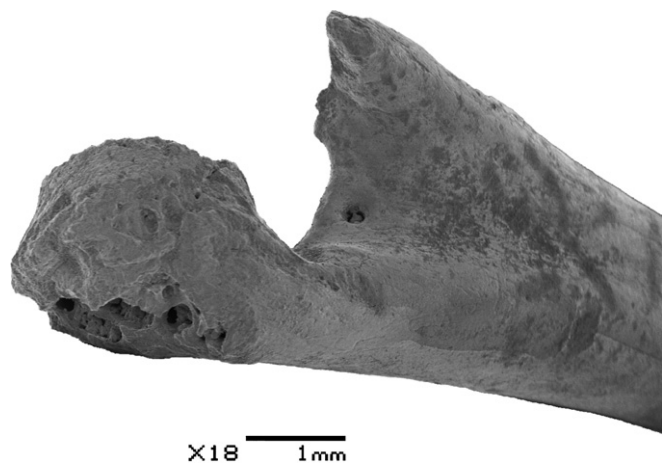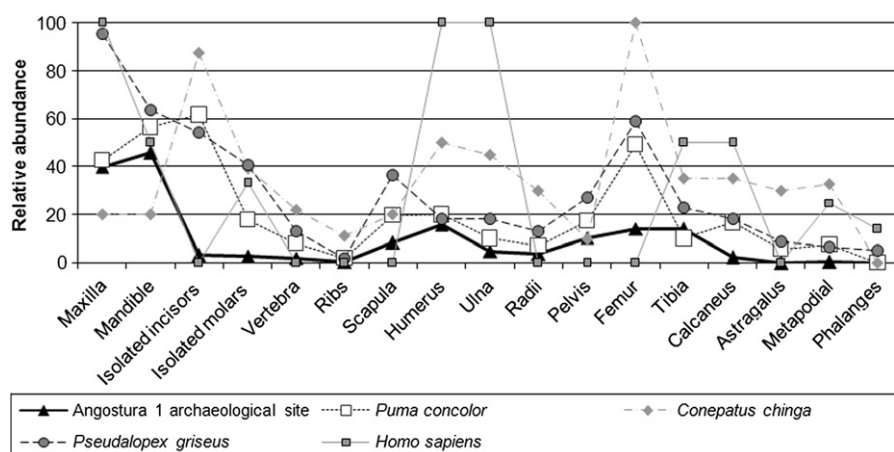
Fig. 5. Relative abundance values for the various anatomical elements from the Angostura 1 archaeological site, compared with small mammal assemblages generated by *Pseudalopex griseus* (Gómez and Kaufmann, 2007), *Puma concolor* (Montalvo et al., 2007), *Conepatus chinga* (Montalvo et al., 2008), and *Homo sapiens* (Crandall and Stahl, 1995).

the greater part of the molars and incisors have been separated from the maxillaries and mandibles.

Marks made by a carnivore were recorded on one phalange. These marks were deep and rounded, similar to those made by canines.

Two kinds of evidence of human modification were identified: cut marks on two *H. brasiliensis* mandibles and a worked bone tool. Both mandibles showed marking on the labial face. On one of these the marks were oriented longitudinally on the ascending ramus (Fig. 6a and b), while on the other they are oriented obliquely between the alveolar margin and the ascending ramus (Fig. 6c and d). This type of marking on small mammal remains would more likely indicate removal of the pelt, rather than the cutting of flesh to disarticulate the mandible and cranium (e.g., Fernández-Jalvo et al., 1999; Quintana, 2005). The bone tool was made from a long bone of an unidentified small mammal (Fig. 7). One of the epiphyses was removed, and the bone was honed to a very sharp point. The apical portion shows evidence of smoothing and polishing, possibly produced during its use as a tool. This piece is very similar to those included in the group of

Table 5
Minimum number of elements (MNE) and relative abundances in the small mammal assemblage from the A1 archaeological site.

	MNE	Relative abundance
Skull	8	3.3
Premaxilla	89	18.6
Maxilla	175	36.6
Mandible	219	45.8
Isolated incisors	31	3.2
Isolated molars	115	3
Vertebra	140	2
Ribs	19	0.3
Scapula	39	8.2
Humerus	75	15.7
Ulna	23	4.8
Radius	17	3.6
Pelvis	50	10.5
Femur	68	14.2
Tibia	66	13.8
Metapodial	23	0.5
Calcaneus	11	2.3
Astragalus	0	0
Phalange	5	0.1
Total	1173	
Average		9.8

Table 6
Breakage in cranial, dental, and post-cranial elements for small mammals from the A1 archaeological site.

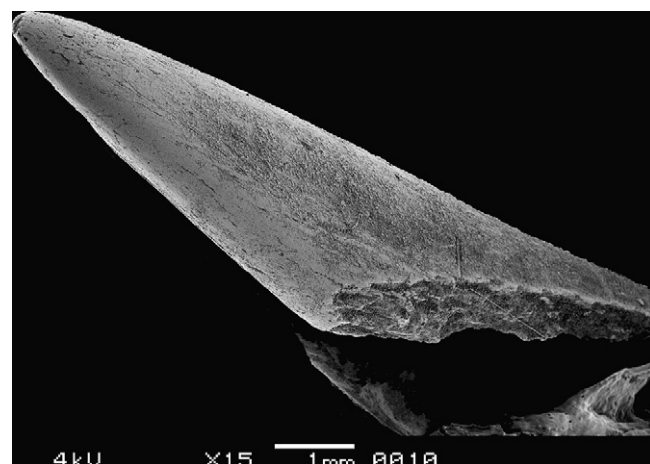|	N	%
Breakage of skulls		
Complete skull	3	0.9
Maxillary with zygomatic	5	1.5
Maxillary without zygomatic	175	51.5
Minor fragments	157	46.2
Molars missing from maxillary	576	79.1
Incisors missing from premaxillary	30	28.6
Breakage of mandible		
Complete mandible	7	3.2
Ascendant ramus broken	34	15.5
Without ascendant ramus	51	23.3
Without ascendant ramus and inferior edge broken	127	58
Molars missing from mandible	535	65.5
Incisors missing from mandible	104	63.4
Breakage of teeth		
Broken molars in situ	116	34.2
Broken isolated molars	29	25.2
Total broken molars	145	31.9
Broken incisors in situ	45	50
Broken isolated incisors	12	38.7
Total broken incisors	57	47.1
Breakage of postcranial elements		
Femur		
Complete	7	6.4
Proximal	59	53.6
Shaft	5	4.5
Distal	39	35.5
Humerus		
Complete	6	6.2
Proximal	17	17.5
Shaft	6	6.2
Distal	68	70.1
Tibia		
Complete	3	2.8
Proximal	40	38.1
Shaft	36	34.3
Distal	26	24.8
Ulna		
Complete	4	17.4
Proximal	19	82.6
Shaft	0	0
Distal	0	0

Table 7
Values of the indices calculated for the A1 archaeological site: f, femur; t, tibia; h, humerus; r, radius; c, ulna; mx, maxilla; mb, mandible; m, molar.

Postcranial/cranial	
f + t + h + r + u/mx + mb + m	94.6
h + f/mx + mb	34.8
Distal/proximal elements	
t + r/f + h	57.1
% Isolated teeth	
% Isolated molars	327.7
% Isolated incisors	148.9

**Fig. 7.** Bone tool recovered from the A1 site, made from a small mammal long bone (MLP 155.4b.g).

"long and very thin" bone tools described by Fernández (1988–1990) from the Cueva Haichol site. Keeping in mind the fragility of such instruments and the presence of a fine point and a larger opposing end where the epiphysis is intact, this author proposed that these items may have had a function similar to present-day brooch pins (Prates, 2008). Finally, it is also worth noting that 6% of the bone remains were burnt, which were recovered from combustion feature, consisting of a compact block of carbonated ash sediment, that differs from the rest of the sediment by its lighter coloration (yellowish).

In regard to post-depositional processes that affected the sample, only 3.4% showed evidence of splitting, cracking, or light exfoliation (i.e., weathering states I and II *sensu* Andrews, 1990). Root markings were observed on 20.5% of bone remains in the sample, with the action of humic acids producing light bioerosion on the cortical surface of the bones. This has created fine, dendritic surface markings, which correspond to the category of "Sphenoichnia" root makings (Mikulás, 1999). Also, 18.6% of the elements show evidence of sedimentary corrosion – possibly caused by soil moisture – and a low incidence (5.2%) of manganese oxide impressions was also observed. No evidence of rounding was found on the ends and protuberances of the bone remains.
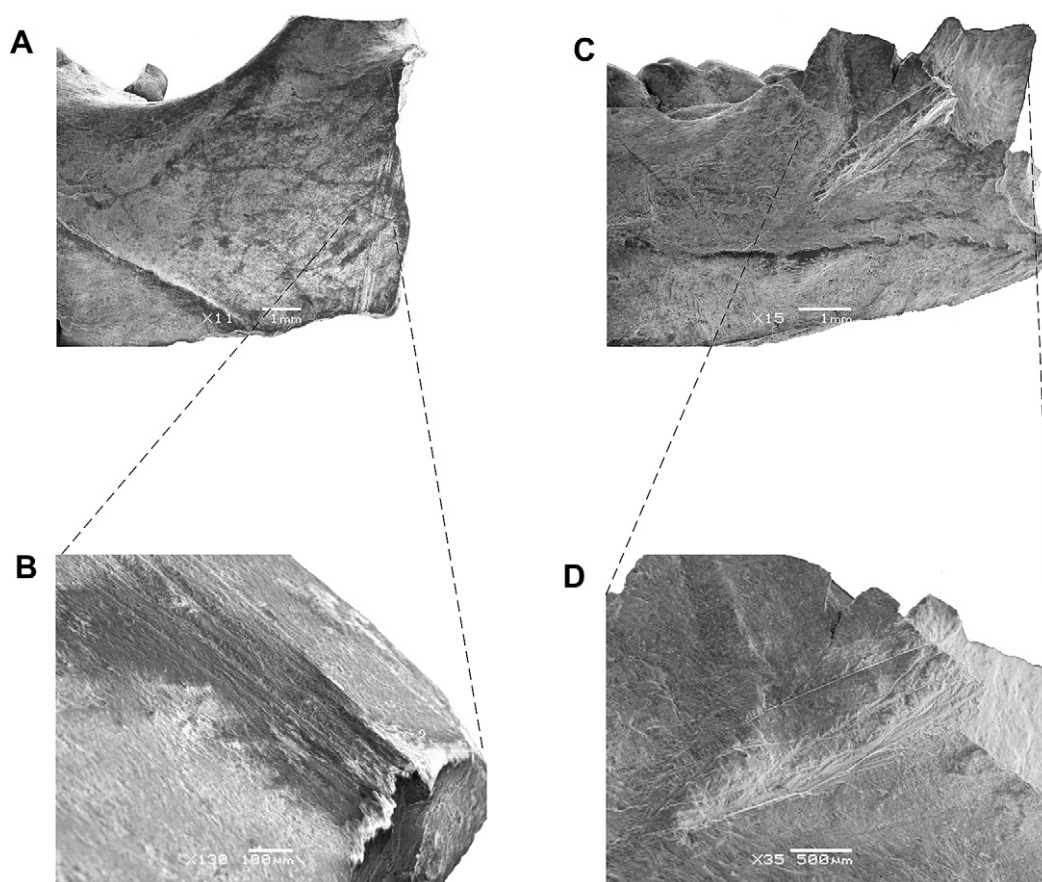
Fig. 6. *Holochilus brasiliensis* mandibles with cut marks. (A) Labial view of the mandible showing markings on the ascending ramus. (B) Area with the markings in the posterior view. (C) Labial view of another mandible, showing makings between the alveolar edge and the ascending ramus. (D) Close-up of the markings.

4.3.2. Negro Muerto site

Taphonomic analysis carried out by Prates (2008) included the macroscopic observation of bone surfaces modifications such as roots, carnivores, rodents, digestive corrosion marks and those generated by human action.

Burrowing rodents as a group are represented mainly by maxillas (49.2%), followed by mandibles (27.9%) and dental remains (6.4%). The only possible evidence for human accumulation is the recording of thermoalteration (indirect evidence), seen on 24.6% of the remains. Also, abundant remains with "Sphenoichnia"-type root markings were found (63.9%). No other types of modifications were seen on the surfaces of the bones (e.g., digestive corrosion).

The elements assigned to *Ctenomys* sp. include isolated teeth (45.4%), mandibles (27.8%), and maxillas (27.8%). Root markings are seen on 54.5% of these specimens, with no specimens showing digestion markings, and with only 18.2% showing evidence of thermoalteration, which were recovered from a similar combustion feature than recorded in A1.

The *H. brasiliensis* remains include mainly mandibles (47.8%) and maxillas (43.5%), along with a smaller number of femurs (8.7%). Root markings are seen on 69.6% of the specimens, but no signs of gastric corrosion or other natural modifications were observed. The only attribute linked with anthropogenic action is thermoalteration, identified on 34.8% of the specimens. Other sigmodontines are represented only by mandibles, which do not display any type of taphonomic modification.

5. Discussion

5.1. Humans as accumulating agents

The presence of cut marks and thermoalteration on *H. brasiliensis* and cavies remains recovered from the A1 site, demonstrates that humans included small mammals as an integral part of their diet. Also, the presence of small mammal bone remains in the sediments within the combustion feature could also show that bones were deposited into the fire, either during or soon after the formation of such sediments, before compaction of the ash would have impeded the incorporation of new materials (Prates, 2008). In addition, the bone tools record indicates the use of small mammals by humans. Moreover, the predominance of larger-sized small mammals (*H. brasiliensis*, *M. australis*, *G. leucoblephara*, and *Ctenomys* sp.; *sensu* Pardiñas, 1999b), indicate prey selection. On this subject, Pardiñas (1999a) proposed that assemblages of thermally-altered small mammal bones associated with human consumption show an elevated percentage of affected remains and a prevailing larger-sized small mammals. Another aspect that reinforces the idea of anthropogenic action is the close association of small mammal remains with other archaeological materials, as well as the fact that they are found at similar density levels (Prates, 2008).

Several lines of evidence from NM indicate that humans were the primary agent that originated this assemblage: (a) the record of the same larger-sized small mammals than A1 site, (b) the marks of thermoalteration in these taxa, (c) the precence of micro-mammals into de combustion feature (hearth), (d) the close spatial association of such remains with other archaeological materials (e.g., stone tools, pottery, hearth), and (e) the absence of small mammal remains in the three test pits carried out in areas around the site. Those test pits of 1 m × 1 m × 1.9 m were excavated around 10 m away from the site, and there were no archaeological remains (Prates, 2008). Also, the low frequency of small-sized sigmodontine rodents, the absence of digestion markings, and the absence of any associated remains of predators, invalidate the idea of non-human predation as being responsible for formation of the deposit (Andrews, 1990; Pardiñas, 1999a; among others). Articulated skeletons were not found during excavation, although these would be expected in a "natural" *in situ* accumulation.

Although the presence of modifications produced by sharp tools is one of the most diagnostic features of archaeological faunal assemblages (Salemme, 1987; Miotti, 1998; Mengoni Goñalons, 1999; Gutiérrez, 2004; among others), such modifications are not typical in small mammal assemblages. This is because the fragility of the skeleton allows butchering without sharp tools, and without requiring the use of joints to orient the cuts (see Quintana, 2005). This observation certainly agrees with ethnographic information recorded for post-Hispanic populations in Patagonia (see Prates, 2008), which has described small mammals being cooked directly on the coals without any prior processing. From this perspective, the low frequency of cut marks identified at both sites should not be used to question the archaeological origin of the accumulations, as such low frequencies could in fact be expected (Prates, 2008).

Although the authors are not aware of existing ethnographic or archaeological references to utilization of *H. brasiliensis* by aboriginal Patagonians, there are abundant archaeological precedents to demonstrate the exploitation of rodents of a similar size in other regions in Argentina (e.g., Quintana et al., 2002; Santiago, 2004; Acosta and Pafundi, 2005; Quintana, 2005; Teta et al., 2005a; Fernández et al., 2009). These authors claim that exploitation of small mammals can be understood as part of a process of intensification that had its beginnings in the mid-Late Holocene at about 2000 years BP. This process was probably set in motion by increases in population densities, which led to gradual reductions in mobility and more intensive usage of a given area's local resources (e.g., Martínez and Gutiérrez, 2004; Neme, 2007). On this subject, Prates (2008), based upon a zooarchaeological studies and taphonomy of the A1 and NM sites, proposed that human groups that occupied the Negro River valley during the Late Holocene relied upon highly diversified diets. These diets would have taken advantage of numerous animal resources and, to a lesser degree, plant resources, and were perhaps more diversified than post-Hispanic ethnographic information would suggest. Such diets included large mammals (*L. guanicoe* and *Ozotocetos bezoarticus*), medium-sized mammals (*D. patagonum*, *C. villosus*, and *Z. pichiy*), small mammals (*M. australis*, *G. leucoblephara*, and *H. brasiliensis*), birds (Rheidae, *E. elegans*, *Anas* sp., and *Fulica* sp.), reptiles (*Chelonoides* sp.), fish (Characiformes and *Percichthys* sp.), fresh-water mollusks (mainly *Diplodon chilensis*), and fruits from the algarrobo tree (*Prosopis* sp.). However, it is also important to note that links to the intensification process must be cautiously considered, in the absence of a larger body of data from earlier time periods, which would allow better evaluation of long-term changes in subsistence strategies. Nevertheless, in the Negro River basin a more diverse diet would be expected, because of the higher availability of resources than in surrounding areas.

5.2. Carnivores as other possible agents of accumulation

At the A1 site, the presence of specimens with digestive corrosion suggests that a portion of the small mammal assemblage is related to the actions of predators. Recent taphonomic studies have shown that carnivores produce high levels of digestion marks on bone and tooth remains (e.g., Andrews and Evans, 1983; Andrews, 1990; Matthews, 2006; Gómez, 2007). As described above, the small mammal assemblage from the A1 site includes both bones without corrosion marks and bones showing varying degrees of digestion (Table 4). This particular pattern is different than assemblages generated by *Homo sapiens* and most of the predatory mammals that inhabit the region (*P. griseus*, *Conepatus chinga*), in which remains tend to be highly digested (Crandall and Stahl, 1995; Deward and Jarardino, 2007; Gómez and Kaufmann, 2007;

Montalvo et al., 2008). However, *P. concolor* generates varying levels of destruction on bones (high levels for medium- and large-sized mammals and both high and low levels for small-sized mammals) (Montalvo et al., 2007). These last authors have proposed that this could be due to some small vertebrates being swallowed whole, rather than being chewed first.

The relative average abundances of skeletal elements from A1 is very low (Table 5), a pattern that also occurs in assemblages produced by carnivores. Mandibles, maxillas, humeri, femurs, and tibias were the most heavily represented elements, while vertebrae, astragali, metapodia, calcanei, and phalanges were the least abundant. In Fig. 5, the relative abundances from the A1 site are compared with those generated by *P. griseus* (Gómez and Kaufmann, 2007), *P. concolor* (Montalvo et al., 2007), *C. chinga* (Montalvo et al., 2008), and *H. sapiens* (Crandall and Stahl, 1995). It can be seen here that the patterns of skeletal part abundances from the archaeological sample are closest to those produced by predation by *P. concolor*. In terms of breakage, the high levels observed in the A1 sample (Table 6) are consistent with breakage values recorded for assemblages produced by both carnivores and humans. Also, most of the broken bones show fractures with rounded edges and smooth surfaces, which suggests that the breakage was not caused by post-depositional processes such as trampling. Andrews (1990) observed that trampling produces elevated breakage of elements with sharp fracture angles and rough edges, as well as a high degree of integrity in the smallest elements.

At the A1 site, the best preservation was seen in cranial elements, with greater loss of distal elements of the limbs and high losses of dentition (Table 7). These results are in agreement with data provided by Andrews (1990) for carnivores, as well as information given by Montalvo et al. (2008) for *P. concolor*. Also, these values coincide in part with those obtained by Deward and Jarardino (2007) for small mammal assemblages produced by *H. sapiens*, where better preservation of cranial and proximal limb elements is seen, although with a higher proportion of teeth remaining *in situ*. The discovery of carnivore marks on one element also helps to substantiate this hypothesis.

P. concolor is a territorial predator that hunts alone and primarily at night, and which consumes a wide variety of prey in the various geographical areas it inhabits (see Iriarte et al., 1990; and literature cited therein). It shows a preference for larger prey including camelids, cervids, and South American ratite birds, although medium-sized prey such as armadillos, hares, and rodents also make up a substantial part of its diet (e.g., Iriarte et al., 1990, 1991; Rau et al., 1991). However, in southern South America, high levels of consumption of small mammals such as the common yellow toothed cavy (*G. leucoblephara*), tucos (*Ctenomys* sp.), and sigmodontine rodents have also been recorded, even though in terms of biomass the importance of this group of rodents would be relatively minor (Iriarte et al., 1990, 1991; Rau et al., 1991; among others). This agrees with the small mammal data recorded in this study and that provided by Prates (2008) regarding the overall faunal record from the A1 site.

The role of *P. concolor* as an accumulating agent for faunal remains in archaeological sites has been emphasized in several research projects in southern South America (Mondini and Muñoz, 2008; Montalvo et al., 2008; Muñoz et al., 2008; among others), including some from the Patagonia region (e.g., Borrero and Martín, 1996; Borrero et al., 2005; Martín and Borrero, 2007). This feline makes its dens in caves and rocky shelters, as well as in open-air sites, crevices between stones, or in dense vegetation (see Pierce and Bleich, 2003; Martín and Borrero, 2007; and references cited therein). It is possible that *P. concolor* may have used dense vegetation typical of the Negro River valley as shelter during periods when the area was not occupied by humans.

5.3. Post-depositional processes

The low frequency of bones with evidence of weathering at both sites suggests a rapid incorporation of material into its stratigraphic context. At the A1 site, both root markings and evidence of sedimentary corrosion and manganese oxide corrosion were seen on the remains. At the NM site only root markings were found. In all cases, the root markings correspond to the "Sphenoichnia" category (Mikulás, 1999). This type of marking indicates the development of herbaceous vegetation cover during the formation of the soil, at the time when the bones were deposited and buried (Montalvo, 2002). The sedimentary corrosion and impregnations of manganese oxide possibly took place because of the presence of soil moisture. Under conditions of permanent moisture in the sediment, small mammal bones are strongly affected, while in dry conditions they are better preserved (Andrews, 1990). However, manganese oxide impregnations are produced by alternating oxidation-reduction cycles (Courty et al., 1989), a process common in sites with a fluctuating water table or ponding of water (Gómez et al., 1999; Gómez, 2000). Neither site contains remains with evidence of hydraulic transport, which can scatter remains and abrade them against the surrounding sediments (Korth, 1979; Fernández-Jalvo and Andrews, 2003).

5.4. Palaeoenvironmental considerations

In order to perform paleoenvironmental interpretations based upon the fossil fauna, possible taphonomic biases that may have affected the creation of the assemblages must be taken into consideration (e.g., Andrews, 1990). The low taxonomic richness and diversity index values of the fossil sample from the A1 site, as compared to modern samples, may reflect intentional selection by humans and carnivores in favor of larger-sized rodents (e.g., *Ctenomys* sp., *G. leucoblephara*, *M. australis,* and *H. brasiliensis*). A similar pattern was seen at the NM site, although the sample size is small (MNI = 24) (Fig. 3). For this reason, it is difficult to make direct comparisons between the relative frequencies of taxa in the archaeological samples and the present-day *T. alba* pellet samples for purposes of paleoenvironmental interpretation. Instead, analysis relies primarily upon presence-absence analysis of taxa with narrowly-defined habitats. Although the validity of this method has been questioned (Simonetti, 1989), the recurring absence of a taxon in a series of samples that are spatially and/or temporally related, can allow its use as a paleoenvironmental indicator (Pardiñas, 1999b; among others).

With the exception of *H. brasiliensis*, the taxa recorded at both archaeological sites are still present in the area today (see Table 3 and Pardiñas et al., 2003, 2004). The presence of *A. molinae, G. griseoflavus, M. australis,* and *G. leucoblephara* in the sequence of the A1 archaeological site, indicates that the small mammal communities in the lower course of the Negro River during the end of the Late Holocene (ca 0.95 ka BP) were associated with Monte-type desert. Furthermore, the presence of *R. auritus* and *Oligoryzomys* sp. suggests the development of open, herbaceous steppe environments associated with bodies of water (Pearson, 1988; Pardiñas et al., 2003, 2004). However, it is also interesting to note the elevated frequencies of *H. brasiliensis* (Fig. 3), an orizomyine found in amphibious habitats, often in low-lying tropical, subtropical, and temperate areas of South America (Hershkovitz, 1955), and which is absent in the study area today. Contreras (1973) and Massoia (1976) established that the southernmost present-day distribution of the species is found along the Chasicó-Bahía Blanca axis (southeastern Buenos Aires province). However, Formoso et al. (2010) recently recorded a new locality for its presence about 110 km further south (20 km south of Pedro Luro at 39°41′S, 62°40′W) in a Patagonian environment. These authors argue that this unique record from this

environment could be explained as evidence of a relict population, a reflection of wider distributions earlier in the Holocene. They alternately propose that this amphibious rodent may have taken advantage of irrigation canals to populate areas to the south of the Colorado River within a context of global warming, which could have favored the more southern dispersion of Brazilian species (Udrizar Sauthier et al., 2005). At any rate, the abundance of this taxon is clearly associated with wetter and warmer conditions (Pardiñas, 1999b). Pardiñas (1999b) and Teta et al. (2005a) proposed that *H. brasiliensis* may also have taken advantage of some of the large Patagonian rivers as fluvial corridors during the climatic changes of the Pleistocene—Holocene, facilitating a wider dispersal of the species.

During the Late Holocene, short episodes of climatic changes have been identified for northeastern Patagonia. The climate was marked by semi-arid conditions, with increases in rainfall that may have led to the expansion of lakes such as Salina de Anzoátegui and Salina Piedra towards the end of the Late Holocene (Schäbitz, 1994, 2003). Also, in the lower course of the Colorado River, the record of *Ceratophrys* (Anura) at the San Antonio and Paso Alsina 1 archaeological sites (ca 1.5—0.4 ka BP), and of *H. brasiliensis* at the El Tigre site (ca 1—0.5 ka BP), would also indicate conditions of higher precipitation and temperature (Stoessel et al., 2008). Similarly, the presence of a subtropical species (*H. brasiliensis*) in the middle and lower Negro River valley (at the A1 and NM sites), between ca. 1000 and 500 BP, suggests that climatic conditions were warmer and wetter than today. The later retraction of the species to the north may have occurred during an episode of cooler and drier conditions, probably associated with the Little Ice Age (between the 16th and 19th centuries) (see Laprida et al., 2009).

6. Conclusions

This paper has discussed the archaeological, taphonomic, and paleoenvironmental implications of the small mammals present at two sites located in northern Patagonia. The remains of these animals were accumulated by the action of two main agents: humans and carnivores. In this sense, diverse evidence indicate the anthropic action (cut marks, prey selection, bone thermoalteration, presence of bones into the hearth, spatial association of bones with other cultural materials, tool manufactured on bone). In both sites several species of rodents (i.e., *H. brasiliensis* and Cavidae) formed a complementary component of the diet of hunter-gatherer groups. Several lines of evidence, such as varying degrees of digestive corrosion, elevated breakage of elements, very low relative average abundances of skeletal elements, the best preservation of the cranial remains, greater loss of distal elements of the limbs and high losses of dentition, also suggest that a portion of the small mammals from the A1 site may have accumulated through the actions of *P. concolor*. Finally, the presence of a subtropical species (*H. brasiliensis*) in both assemblages demonstrates that this taxon inhabited northern Patagonia as a relictual population, until becoming retraction or local extinction in the climatic context of the Little Ice Age. It is not known yet how this relict meridional population may have differed from more northern ones.

Acknowledgements

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