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Micromammals, taphonomy, paleoenvironments and human occupation during the Holocene in Arroyo Malo-3 (west-central Argentina)

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ABSTRACT: Micromammal remains from the archaeological sequence of Arroyo Malo-3 (AMA-3, 34º51'18''S, 69º53'00''W; soutwestern Mendoza, Argentina) are taxonomically identified, and taphonomic and paleoenvironmental conditions assessed. Small mammal remains (NISP = 7239, MNE= 7211, MNI = 730) were recovered from Holocene temporal units (Unit III = 8900-3810 years ^{14}C BP; Unit II = 3810-2200 years ^{14}C BP; Unit I = 2200-~100 years ^{14}C BP). The taphonomic evidences such as pellets preserved in the stratigraphy, mostly moderate but also high digestive marks on teeth and postcraneal bones, and relative abundance patterns of skeletary parts, indicate that the main accumulating agents of the micromammal assemblages recovered from the units of AMA-3 would have been the Accipitriformes, possibly *Geranoaetus melanoleucus* (black-chested buzzard-eagle) or *Buteo polyosoma* (red-backed hawk). The scarce record of weathered bones, the absence of trampling marks, roots, sediment corrosion and water transport and the discovery of numerous specimens with manganese oxide impressions suggest that the remains had a rapid burial and good preservation, although with high moisture levels. The micromammal assemblages of AMA-3 showed a remarkable taxonomic stability, with some minor changes towards the Late Holocene. The major changes occurred in the recent micromammal assemblages close to the site, marked by an increase of shrubs attributable to human impact possibly produced by domestic livestock reinforced in the south of Mendoza since the 19th century. The paleoenvironmental and taphonomical information presented provides a relevant framework to improve archaeological studies of the biogeography and subsistence system of southern Mendoza hunter-gatherer populations during the Holocene.

KEYWORDS: RODENTS, MARSUPIALS, PELLET RAPTORS, ZOOARCHAEOLOGY, SOUTHERN MENDOZA, ARGENTINA

RESUMEN: Se identificaron taxonómicamente restos de micromamíferos provenientes del sitio arqueológico Arroyo Malo-3 (AMA-3, 34º51'18''S, 69º53'00''O; suroeste de Mendoza, Argentina) y se analizaron aspectos tafonómicos y paleoambientales. Los restos de micromamíferos (NISP = 7239, MNE= 7211, MNI = 730) fueron recuperados de unidades correspondientes al Holoceno (Unidad III = 8900-3810 años ^{14}C AP; Unidad II = 3810-2200 años ^{14}C AP; Unidad I = 2200-~100 años ^{14}C AP). Las evidencias tafonómicas tales como egagrópilas preservadas en la estratigrafía, patrones de abundancia relativas de partes esqueletales y restos con marcas de digestión moderada y fuerte, indican que el principal agente acumulador de los conjuntos de micromamíferos recuperados de AMA-3 podrían haber sido aves Accipitriformes, posiblemente *Geranoaetus melanoleucus* (águila mora) o *Buteo polyosoma* (aguilucho común).

El escaso registro de huesos meteorizados, la ausencia de marcas de pisoteo, raíces, corrosión sedimentaria y transporte hídrico, junto a la evidencia de numerosos especímenes con impresiones de óxido de manganeso, sugieren que los mismos tuvieron un enterramiento rápido y buena preservación, aunque con altos niveles de humedad. Los conjuntos de micromamíferos de AMA-3 mostraron una marcada estabilidad taxonómica, con algunos cambios menores hacia el Holoceno tardío. El cambio mayor ocurrió en los conjuntos actuales cercanos al sitio, señalando un aumento de la arbustización atribuible al impacto antrópico producido por el ganado doméstico, afianzado en el sur de Mendoza desde el siglo XIX. La información tafonómica y paleoambiental presentada provee una estructura relevante para optimizar los estudios biogeográficos y de sistemas de subsistencia de los cazadores y recolectores del sur de Mendoza durante el Holoceno.

PALABRAS CLAVE: ROEDORES, MARSUPIALES, EGAGRÓPILAS, ZOOARQUEOLOGÍA, SUR DE MENDOZA, ARGENTINA

INTRODUCTION

The taphonomic analysis of micromammal remains recovered from archaeological sites is important because it provides information on the depositional and taphonomic agents that have participated in the formation of the assemblages (*e.g.*, Andrews, 1990; Fernández-Jalvo & Andrews, 1992; Stahl, 1996). Having identified the main taphonomic agents can lead us to a proper comparison with recent actualistic parameters and, subsequently, to a paleoenvironmental reconstruction (*e.g.*, Andrews, 1995; Stahl, 1996; Pardiñas, 1999a; Terry, 2010a, 2010b).

Worldwide, studies of small mammals recovered from archaeological contexts have been mainly focused on taphonomy (*e.g.*, Andrews, 1990; Simonetti & Cornejo, 1991; Fernández-Jalvo & Andrews, 1992; Hockett & Bicho, 2000; Fernández-Jalvo, 2003; Weissbrod *et al.*, 2005; Matthews *et al.*, 2006; Deward & Jarardino, 2007) and palaeoecology (*e.g.*, Andrews *et al.*, 1979; Simonetti, 1989; Andrews, 1995; Vigne & Valladas, 1996; Reed, 2003, 2007, 2011; Schmitt, 2004; Matthews *et al.*, 2005; Arcos *et al.*, 2010). However, studies that integrate both taphonomy and paleoecology disciplines are still scarce (*e.g.*, Fernández-Jalvo, 1995, 1996; Denys, 1997; Fernández-Jalvo *et al.*, 1998; Reed & Denys, 2011; Stoetzel *et al.*, 2011; Pokines, 2012). In Argentina this situation is not different, where although in recent decades investigations of micromammals from archaeological sites have greatly increased, studies in which both aspects, paleoenvironmental and taphonomic, are comprehensively dealt remain scarce (Pardiñas, 1996-1998, 1999a; Gómez *et al.*, 1999; Pardiñas *et al.*, 2000; Teta *et al.*, 2005; Fernández *et al.*, 2009a, 2011a, 2012; Fernández, 2012a, 2012b; Scheifler *et al.*, 2012).

In the south of Mendoza province, the work of Atencio (2000) in Cueva Arroyo Colorado and Neme *et al.* (2002) in Arroyo Malo-3 initiated the research on small mammal remains recovered from archaeological sites. With a taphonomic and paleoenvironmental focus, these authors demonstrated the importance of this kind of analysis for the archaeology of the region. Subsequently, the zooarchaeological works of Gasco *et al.* (2006) in Caverna de Las Brujas, Fernández *et al.* (2009a) in Cueva Arroyo Colorado and Fernández (2010) in Agua de La Mula, deepened these studies using samples of pellets from birds of prey as actualistic parameters.

Arroyo Malo-3 (AMA-3) is an emblematic archaeological site in southwestern Mendoza province, with a sequence that covers most of the Holocene where numerous investigations were conducted involving comprehensive archaeological analysis (Neme, 2002, 2007); chronostratigraphic studies (Diéguez & Neme, 2003); analysis of the lithic technology (Pérez Winter, 2009a, 2009b, 2010); plant macroremains (Llano, 2008); avifaunal remains (Giardina, 2010) and, as mentioned above, on micromammals (Neme *et al.*, 2002). In the latter case, the cited authors studied from a taphonomic and paleoenvironmental point of view micromammal assemblages from the quadrat A-1. However, the aims of this work are to make a taphonomic and paleoenvironmental analysis based on small mammals recovered from a new quadrat (B-1); and to make a comparison with the results achieved by Neme *et al*. (2002), in order to expand the existing information and to have a comprehensive approach of the micromammals recovered from the site. In addition, this taphonomic and paleoenvironmental analysis is related to southern Mendoza human occupation model.

MATERIAL AND METHODS

The archaeological site and regional setting

The AMA 3 archaeological site (34º51'18"S, 69º53'00"W; 2160 m asl) is a rockshelter of 13 m of opening, 3 m high and 7.5 m depth composed of basalt and andesite that belong to the Cerro Guanaquero Formation (Neme, 2007). It is located in the southwest of Mendoza province, in the high valley of Atuel river, near the mouth of Arroyo Malo in that river and three km from the Laguna El Sosneado (Figure 1). From a phytogeographic point of view, the AMA-3 site is emplaced in the Patagonian province (*sensu* Cabrera, 1976). This unit is characterized by a cold and dry weather, with strong winds from the Pacific anticyclone and winter precipitations of nival type (600 to 1000 mm). The dominant vegetation is the shrub and herbaceous steppes, and cordilleran meadows, which are developed on basaltic, sandy, stony and poor in organic matter soils (Cabrera, 1976). The community of steppes is mainly dominated by: *Mulinum spinosum*, *Ephedra ochreata*, *Chuquiraga rosulata* and species of the genus *Azorella*, *Adesmia*, *Poa*, *Senecio* and *Maihuenia* (Cabrera, 1976). The AMA-3 site is near the ecotone of the Patagonian province with the Altoandina phytogeographic province (> 3000 m asl, *sensu* Cabrera, 1976), the latter being characterized for having a cold weather with a winter precipitation regime (mainly as snowfall), which come from the Pacific anticyclone. The chamaephytes and shrubs steppes predominate in this province, and the cordilleran meadows and semi-desert of lichens are common, especially the genera *Adesmia*, *Cassia*, *Oxalis*, *Verbena* and *Mulinum* (Cabrera, 1976).

This area is characterised by the presence of accipitriforms birds such as *Geranoaetus melanoleucus* (black-chested buzzard-eagle) and *Buteo polyosoma* (red-backed hawk), the falconiforms *Falco peregrinus* (peregrine falcon), *Falco sparverius* (american kestrel), *Milvago chimango* (chimango caracara) and *Caracara plancus* (crested caracara), and the strigiforms *Tyto alba* (barn owl), *Bubo virginianus magellanicus* (magellanic horned owl), *Asio flammeus* (short-eared owl) and *Athene cunicularia* (burrowing owl).

The excavations at AMA-3 site were made in four field trips during the summer months of 1992, 1995, 1996 and 2000. In the first one, a survey of 50 cm x 50 cm was performed and 9 artificial levels of 10 cm deep were excavated, which their archaeological potential was the support for posterior excavations. Between 1995 and 1996 the quadrat A-1 of 1 x 2 m was opened, located in the centre of the rockshelter, where 35 artificial levels of 5 cm were extracted until reaching the bedrock to a depth of 1.75 m (Neme, 2007). Finally, in 2000, the quadrat B-1 of 4 m^2 was excavated, reaching a depth of 2 m by 40 artificial levels of 5 cm each (Diéguez & Neme, 2003).

The stratigraphic analysis was performed by Diéguez & Neme (2003) based on changes in the granulometry and coloration of the sediments, were able to differentiate the sequence of 2 m thick in three main layers (Figure 1). In this sense, the first change in stratigraphy occurs at 45 cm depth, with the passage of brownish gray sediment to a light gray one, predominating sandy sediment with clasts of various sizes from landslides from the rockshelter roof (Figure 1). Subsequently, between 75 cm and 145 cm depth the same sediment remains. However, below this layer the sediment becomes finer and homogeneous, the color is dark gray and there is a decrease in psammitic fraction, finally the sediment rests on bedrock (Diéguez & Neme, 2003).

The Table 1 and Figure 1 (see bellow) show the radiocarbon dates and its location in the sequences of both quadrats. Samples were obtained from charcoal; except for one that was obtained from a bone remain of an extinct megamammal (see Diéguez & Neme, 2003). Some of the organic-rich levels were sampled for radiocarbon dating. All ^{14}C dates obtained were calibrated using the CalPal Hulu-2007 calibration curve (Weninger *et al*., 2007).

In order to make comparisons this study followed the proposal of previous studies made in AMA-3 (*e.g*., Neme, 2002, 2007; Neme *et al*., 2002), where the sequence of the site was divided into three temporal units (Unit III = layers 40-24, 8900-3810 years ^{14}C BP [10,030-4210 years cal

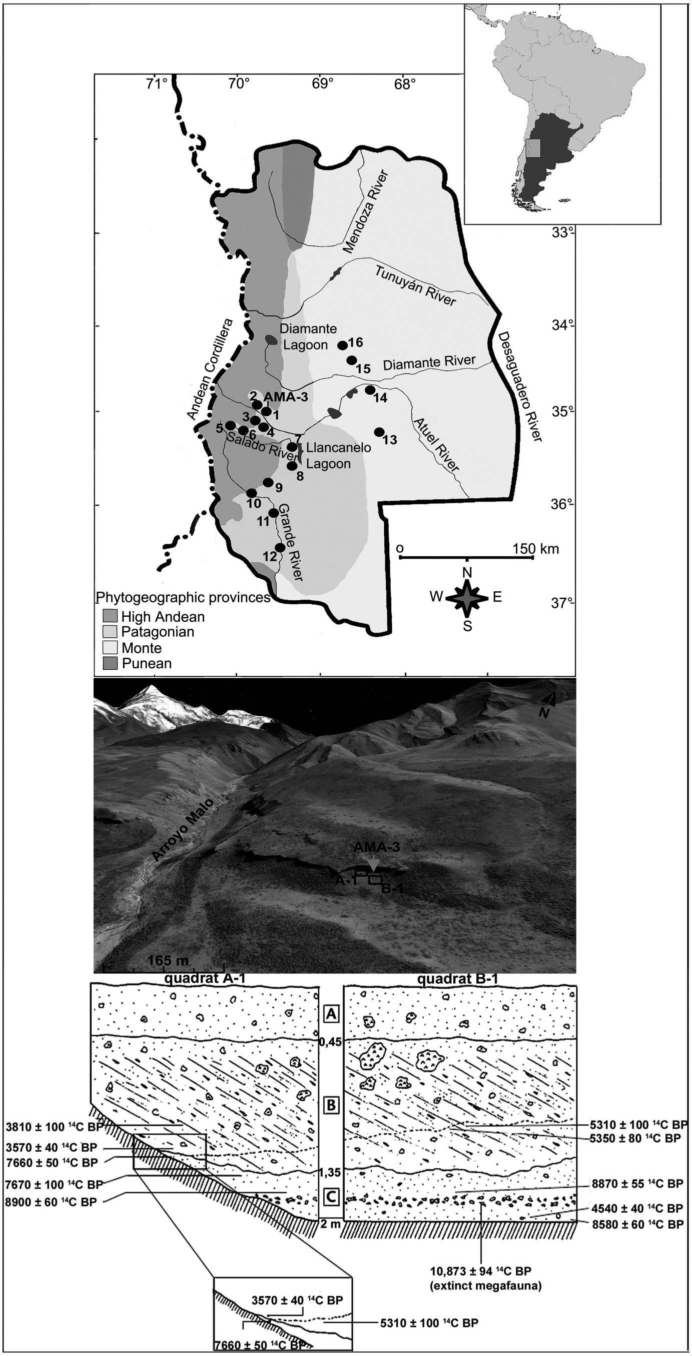

FIGURE 1

Map and detail of the study area (above and middle), Mendoza province, Argentina, showing the emplacement of the quadrats A-1 and B-1 (unscaled) of Arroyo Malo-3 (AMA-3) and stratigraphic profile (below) following Diéguez & Neme (2003: 88); numbers in the map correspond to recent raptor pellets samples: 1. Arroyo Malo; 2. Laguna El Sosneado; 3. Arroyo Panchino I; 4. Arroyo Panchino II; 5. 6 km S of Las Leñas; 6. Laguna de la Niña Encantada; 7. Volcán Carapacho; 8. Volcán Malacara; 9. Caverna de Las Brujas; 10. 10 km W of Bardas Blancas; 11. La Pasarela; 12. Los Frisos; 13. Agua de La Mula; 14. Gruta del Indio; 15. Río Seco La Hedionda; 16. 50 km NW of San Rafael. Main phytogeographic units according to Cabrera (1976).

Quadrat	Layer	Material	Lab Code	^{14}C date	Calibrated date
A-1	12	charcoal	LP-958	2200 ± 50 BP	2277 ± 71 BP
A-1	24	charcoal	LP-946	3810 ± 100 BP	4210 ± 152 BP
A-1	27	charcoal	NSRL-11721	3570 ± 40 BP	3869 ± 58 BP
A-1	28	charcoal	NSRL-11722	7660 ± 50 BP	8469 ± 49 BP
A-1	31,32,33	charcoal	LP-783	7670 ± 100 BP	8484 ± 82 BP
A-1	35	charcoal	AA-26193	8900 ± 60 BP	10,030 ± 112 BP
B-1	23 N	charcoal	LP-1279	5350 ± 80 BP	6134 ± 105 BP
B-1	23 S	charcoal	LP-1267	5310 ± 100 BP	6099 ± 113 BP
B-1	35	charcoal	NSRL-11723	8870 ± 55 BP	9989 ± 131 BP
B-1	37	bone	AA-58287	10,873 ± 94 BP	12,846 ± 98 BP
B-1	39	charcoal	NSRL-11720	8580 ± 60 BP	9569 ± 50 BP
B-1	40	charcoal	NSRL-11719	4540 ± 40 BP	5193 ± 99 BP

TABLE 1

Radiocarbon dates in Arroyo Malo-3 archaeological site.

BP]; Unit II = layers 24-12, 3810-2200 years ^{14}C BP [4210-2227 years cal BP]; Unit I = layers 12-1, 2200 years ^{14}C BP- ~100 relative chronology based on an exotic leporid [2227 years cal BP- ~100 BP]). It is interesting to note that Diéguez & Neme (2003) found some chronostratigraphyc problems between unit A-1 and unit B-1. On the level 38 of the unit B-1, the date of *ca*. 4500 years ^{14}C BP below the levels of *ca*. 8900 years ^{14}C BP was interpreted by the authors as a migration of material due to the fossorial animals activity. A gap of *ca*. 3000 years between levels 27 and 28 was found in the unit A-1, showing the absence of dating for the Mid-Holocene, which was present in the quadrant B-1 (*ca*. 5300 years ^{14}C BP). This anomaly in the quadrant A-1 was explained by the authors based on the topography of the bedrock and rockfall events near the dripline, which would have made a difference in the rate of deposition between the two quadrats during the Mid Holocene (Diéguez & Neme, 2003). The record of a phalange of an extinct megamammal –Xenarthra, Tardigrada indet.– (Quadrat B-1, Unit III, Layer 37), dated *ca*. 10,800 years ^{14}C BP together with archaeological materials of the first human occupation of the rockshelter dated on charcoal between 8900 and 8500 years ^{14}C BP, show that the use of shelter by this extinct fauna would not have been contemporaneous with the earliest human occupation (Neme, 2002, 2007; Diéguez & Neme, 2003). However, the site presents a stratigraphic and chronological internal consistency which allows an accurate management of information (Diéguez & Neme, 2003; Neme, 2007).

On the basis of the chronostratigraphic analysis, bones and teeth of rodents and marsupials (number of identified specimens [NISP] = 7239; minimum number of elements [MNE] = 7211; minimum number of individuals [MNI] = 730) are assigned to the temporal units (see above). In addition, the small mammals archaeological remains were recovered with a 2 mm-sized mesh screen, examined with a stereomicroscope and housed at the Museo de Historia Natural de San Rafael (San Rafael, Mendoza, Argentina), under the number MHNSR-000002.

Recent samples

In order to explore the paleoenvironmental significance of archaeological samples of AMA-3, comparisons with recent micromammal communities in Central South Mendoza province were assessed through the analysis of 16 fresh pellet samples of raptors (Strigiformes and Accipitriformes) (Figure 1), which were recovered from nest and roosting by the authors, and taken from the published literature. These samples reflect main environmental types that occur in the Central South Mendoza province (Altoandina-Patagonian steppe ecotone, Patagonian steppe, Patagonian steppe-Monte desert ecotone and Monte desert). The studied samples are: 1) Arroyo Malo (*G. melanoleucus*, 34º51'18''S, 69º53'00''W [nest above AMA-3], MHNSR-0096, Fernández, 2012a); 2) Laguna El Sosneado (*T. alba*, 34°50'34''S, 69°54'34''W, MHNSR-0097, Fernández *et al*., 2009b); 3) Arroyo Panchino I (*B. v. magellanicus*, 34°56'45''S, 69º50'55''W, MHNSR-0098, Fernández, 2012a); 4) Arroyo Panchino II (*B. polyosoma*, 34°56'37''S, 69°50'7''W, MHNSR-0099, Fernández, 2012a); 5) 6 km S of Las Leñas (*T. alba*, 35°11'59''S, 70°3'27''W, MHNSR-0100, Fernández *et al*., 2009a, 2009b); 6) Laguna de la Niña Encantada (*B. v. magellanicus*, 35º09'38''S, 69º52'09''W, housed at Colección Mastozoológica Elio Massoia, Fundación de Historia Natural Félix de Azara [Ciudad Autónoma de Buenos Aires, Buenos Aires, Argentina] and Colección de Material de Egagrópilas y Afines «Elio Massoia» del Centro Nacional Patagónico [Puerto Madryn, Chubut, Argentina] under the number CNP-E-55-56-409, Massoia *et al*., 1994; Nabte *et al*., 2006; Pardiñas *et al*., 2008); 7) Volcán Carapacho (*T. alba*, 35º36'S, 69º12'W, CNP-E 19, Pardiñas *et al*., 2008); 8) Volcán Malacara (raptor indet., 35°47'26''S, 69°29'13''W, MHNSR-0101, Fernández, 2012a); 9) Caverna de Las Brujas (raptor indet., 35º45'S, 69º49'W, housed at Laboratorio de Geo-arqueología de la Facultad de Filosofía y Letras UNCUYO, Gasco *et al*., 2006); 10) 10 km W of Bardas Blancas (raptor indet., 35º52'28''S, 69º52'46''W, CNP-E 289, Pardiñas *et al*., 2008); 11) La Pasarela (raptor indet., 36º18'46''S, 69º40'03''W, CNP-E 198, Pardiñas *et al*., 2008); 12) Los Frisos (raptor indet., 36º28'20''S, 69º38'54''W, CNP-E 199, Pardiñas *et al*., 2008); 13) Agua de La Mula (*G. melanoleucus*, 35º22'34,6''S, 68º14'42,1''W, MHNSR-0093, Fernández, 2010); 14) Gruta del Indio (*B. v. magellanicus*, 34º45'S, 68º22'W, MHNSR-0095, Fernández *et al*., 2009b); 15) Río Seco La Hedionda (*T. alba*, 34º29'S, 68º33'W, Colección Mastozoológica Elio Massoia, Fundación de Historia Natural Félix de Azara, Massoia *et al*., 1997); 16) 50 km NW of San Rafael (*B. v. magellanicus*, 34º15'S, 68º40'W, Colección Mastozoológica Elio Massoia, Fundación de Historia Natural Félix de Azara, Nabte *et al*., 2006).

Finally, these raptors feed mainly on small mammals and produce bone assemblages from low to moderate degree of destruction (Andrews, 1990; Gómez, 2005; Iglesias, 2009; Fernández, 2012a). Thus, these species could be considered good estimators of small mammal communities in a specific area. However, some biases may alter the samples, due to differences their home ranges, the habits representation (diurnal/nocturnal; solitary/colonial) and size categories (see below). In spite of these potential biases, the small mammals data matrix collected in the study area, is a solid framework to compare with small mammals assemblages from AMA-3 site.

Taphonomy and paleoenvironmental methodological models

The taphonomic approach followed the methodology used by Andrews (1990) and Fernández-Jalvo & Andrews (1992). The relative abundances of skeletal elements were evaluated with the representation of each element in the sample, calculated (MNEi) on the basis of the expected number for each skeletal element per individual (Ei) and the minimum number of individuals (MNI) by using the following formula: MNEi / (Ei x MNI) x 100. In order to assess the relationships between cranial and post-cranial elements, two indices were calculated: ([femur + tibia + humerus + radius + ulna] x 16 / [mandible + maxilla + molars] x 10) x 100; and ([humerus + femur] / [mandible + maxilla]) x 100. In order to assess the proportions between distal and proximal elements of the limbs, the following index was calculated: ([tibia + radius] / [femur + humerus]) x 100. Two other indices were calculated to evaluate the rate of tooth loss ([premaxillary alveoli + mandibular alveoli] / [incisors]) x 100, and ([maxillary alveoli + mandibular alveoli] / [molars]) x 100.

Additionally, Pardiñas (1999a, 1999b) developed two indices based on an extensive framework of the sizes and habits of the micromammalian species derived from recent raptor pellet samples and human accumulations to distinguish the action of birds of prey and humans in the genesis of the assemblages: 1) Size Index (SI) = (MNI small [mammals with head and body <120 mm] + MNI medium [120-170 mm] / MNI large [170-250 mm] + MNI very large [>250 mm]) x 100. Values above 100 indicate bird raptors action, and below this number could point human activity. This situation is due to in contrast of the most raptors, humans feed on larger small mammals. 2) Predictability Index (PI) = (MNI gregarious + MNI colonial + MNI grouped) / (MNI cryptic + MNI solitary) x 100. Values above 100 would suggest accumulations produced by humans and diurnal raptor birds (Accipitriformes), and and below this number could indicate nocturnal raptor birds (Strigiformes). The hystricognath rodents are included in the categories of large, very large, colonial, gregarious and grouped; sigmodontine rodents and marsupials correspond to the categories of medium, small, cryptic and solitary.

Post-depositional taphonomic agents such as weathering, trampling, root action, transport, and diagenesis were considered following the studies of Korth (1979), Andrews (1990) and Fernández-Jalvo & Andrews (2003).

Taxonomic identifications were made exclusively based on cranial and dental remains by comparison with reference materials from the Colección de Mamíferos del Museo de Ciencias Naturales de La Plata (La Plata, Buenos Aires, Argentina), as well as with bibliographic sources (*i.e.*, Fernández *et al.*, 2011b). In addition, fragmentary remains of small specimens of exotic Leporidae (rabbits and hares) and the rodents *Ctenomys* (tuco-tuco) and *Eligmodontia* (silky desert mouse) are difficult to identify to the species level, therefore, remained a taxonomy at the genus level.

The paleoenvironmental analysis is based on the use of small mammals as indicators of environmental conditions. The presence or absence of several species as well as their frequencies, in conjunction with the environmental requirements, allows as to develop paleoecological inferences (*e.g.*, Andrews, 1995; Pardiñas, 1999a). Recent raptor pellet samples are compared with fossil samples in the theoretical framework of the modern analogue method (Overpeck *et al.*, 1985). A principal component analysis (PCA) and cluster analyses was performed in order to explore the multivariate relationship between archaeological and recent micromammal samples. The PCA worker over a data matrix composed by species abundances (MNI%) per sample. Cluster analyses were based on the same data matrix (MNI%), being the Euclidean distance the similarity coefficient calculated and UPGMA (Unweighted Pair Group Method Average) to produce phenograms. Statistical analyses were made with the program PAST (PAleontological STatistics) Version 2.07, a software of common use in palaeoecology.

RESULTS

Taphonomic analysis

More than 90% of the remains exhibited digestive corrosion marks in all the AMA-3 units (Table 2), which are mostly in the light, moderate and heavy categories (Andrews, 1990). In one part of the incisors corrosion was concentrated at the edges, in another part, corrosion was spread over a larger area, leaving a wavy surface and, in another place, the enamel was reduced to small islets on the dentine. Some molar exhibited cusps with a more rounded contour, others showed a slight pit on the dentine and many of them lacked enamel or had a very strong pit. There were numerous postcranial remains with evidence of pits in the articular surfaces (Figure 2A), some with eroded or polished appearance and others with a wavy diaphysis and an epiphysis strongly digested (Figures 2 B, C). Interestingly, in the Unit I a pellet fragment was recovered (Figure 2D) as well as 138 bone specimens with evidence of hairs from pellets (3%, Figure 2E).

The relative abundance was low in all units, being even lower in Unit III. In the three units, a similar pattern of skeletal part representation was observed, where the most abundant were the maxillas, mandibles, humeri, pelvis, femurs and tibias; the less abundant were the ribs, astragalus, metapodia and phalanges, possibly lost in sieving (Figure 3).

The 53.3% of all specimens recovered from AMA-3 were fractured. The Unit I has the highest percentage of fracture (57%), followed by Unit III (50.7%) and Unit II (45.6%). In Table 3, the different types of fracture in the items mentioned in the methodology proposed by Andrews (1990) and Fernández-Jalvo & Andrews (1992) is shown. Complete skulls were not recovered in any of the units and most of them corresponded to maxillas without the zygomatic arch. The percentages of tooth loss were close to 30%. The rates of complete mandibles were very scarce, and the ones fractured exhibited an equal representation among the different categories in all units. There was a

	Digestion classes *sensu* Andrews (1990)									
	Absent		**Light**		**Moderate**		**Heavy**		**Extreme**	
	(N)	**%**	**(N)**	**%**	**(N)**	**%**	**(N)**	**%**	**(N)**	**%**
Unit I										
Digestion of teeth										
Incisors *in situ*	66	13.5	172	35.1	84	17.1	161	32.9	7	1.4
Isolated incisors	24	7.1	85	25.1	100	29.5	125	36.9	5	1.5
Incisors Total	90	10.8	257	31	184	22.2	286	34.5	12	1.4
Molars *in situ*	42	2	541	26	773	37.2	705	33.9	19	0.9
Isolated molars	3	0.9	86	26.8	98	30.5	134	41.7	0	0
Molars Total	45	1.9	627	26.1	871	36.3	839	34.9	19	0.8
Digestion in postcranials										
Proximal femur	20	4.1	201	41.3	151	31	112	23	3	0.6
Distal humerus	66	18.3	186	51.7	57	15.8	50	13.9	1	0.3
Unit II										
Digestion of teeth										
Incisors *in situ*	5	4.4	42	37.2	24	21.2	42	37.2	0	0
Isolated incisors	2	1.6	30	23.4	35	27.3	60	46.9	1	0.8
Incisors Total	7	2.9	72	29.9	59	24.5	102	42.3	1	0.4
Molars *in situ*	1	0.2	62	12.1	219	42.6	232	45.1	0	0
Isolated molars	14	10.6	20	15.2	39	29.5	59	44.7	0	0
Molars Total	15	2.3	82	12.7	258	39.9	291	45	0	0
Digestion in postcranials										
Proximal femur	1	0.8	45	37.8	41	34.5	32	26.9	0	0
Distal humerus	4	2.7	70	47.9	45	30.8	27	18.5	0	0
Unit III										
Digestion of teeth										
Incisors *in situ*	4	6.1	23	34.8	6	9.1	33	50	0	0
Isolated incisors	17	16.5	20	19.4	30	29.1	36	35	0	0
Incisors Total	21	12.4	43	25.4	36	21.3	69	40.8	0	0
Molars *in situ*	4	1	49	11.9	183	44.4	176	42.7	0	0
Isolated molars	8	9.2	9	10.3	33	37.9	37	42.5	0	0
Molars Total	12	2.4	58	11.6	216	43.3	213	42.7	0	0
Digestion in postcranials										
Proximal femur	13	16.7	35	44.9	17	21.8	13	16.7	0	0
Distal humerus	4	5.6	45	62.5	14	19.4	9	12.5	0	0

TABLE 2

Representation of the various categories of digestive corrosion for the small mammal assemblages from Arroyo Malo-3 archaeological site.

high loss of molars and a low loss of incisors of the mandible.

Exiguous broken molars were recovered in all units. However, there were higher percentages of broken incisors, reaching 60% in the Unit III. Also, in all units, the isolated incisors and molars showed higher rates of fracture compared with those that were *in situ*.

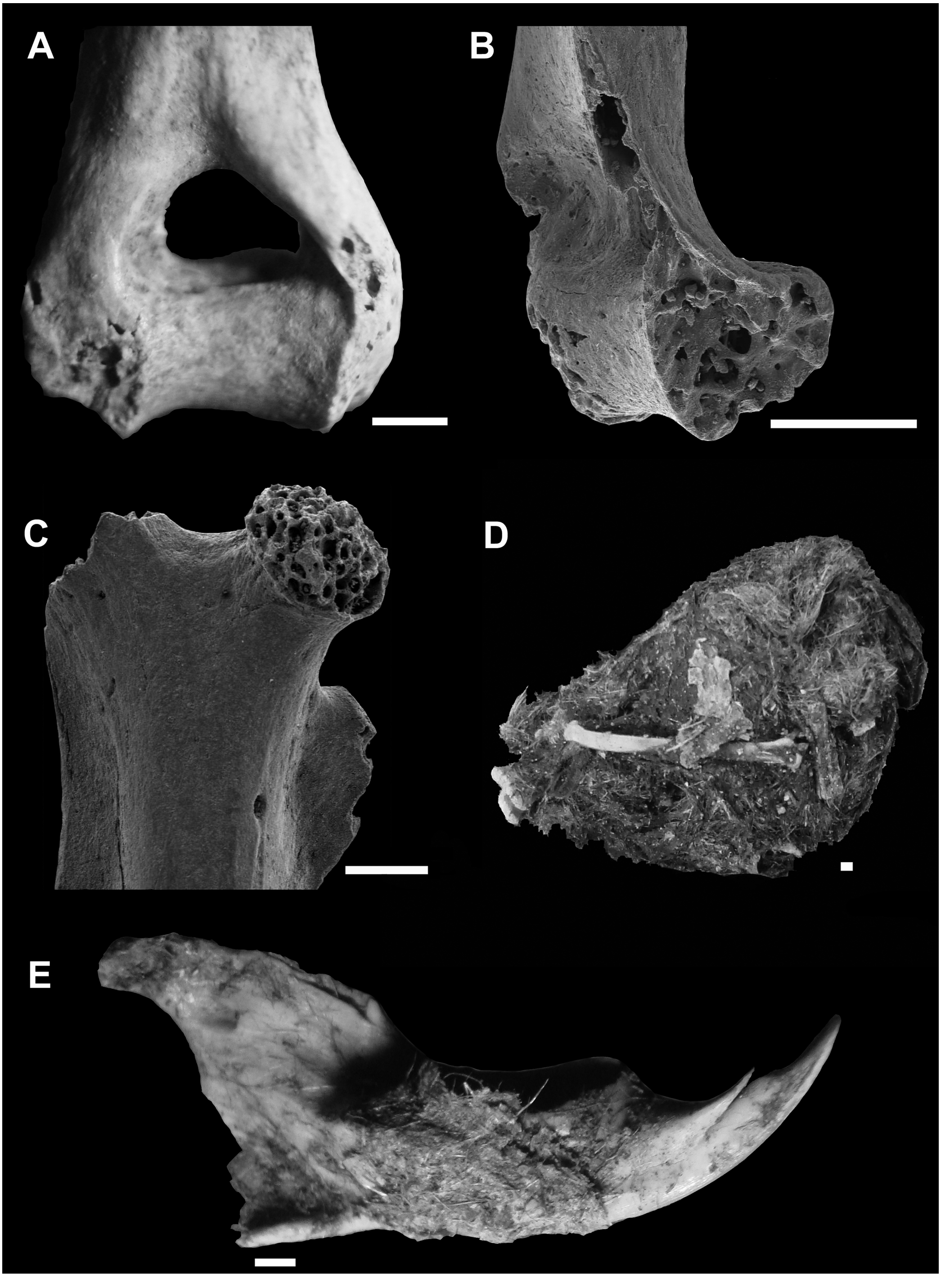

FIGURE 2

Examples of raptor evidence at different units of Arroyo Malo-3. A. Humerus of Caviidae showing light digestive corrosion on the distal epiphysis (Layer 6, Unit I); B. Humerus of Sigmodontinae showing heavy digestive corrosion on the distal epiphysis (Layer 17, Unit II); C. Femur of Sigmodontinae showing heavy digestive corrosion on the proximal epiphysis (Layer 26, Unit III); D. Pellet (Layer 2, Unit I); E. Mandible of *Euneomys* with remains of pellets (Layer 1, Unit I). Scales = 1 mm.

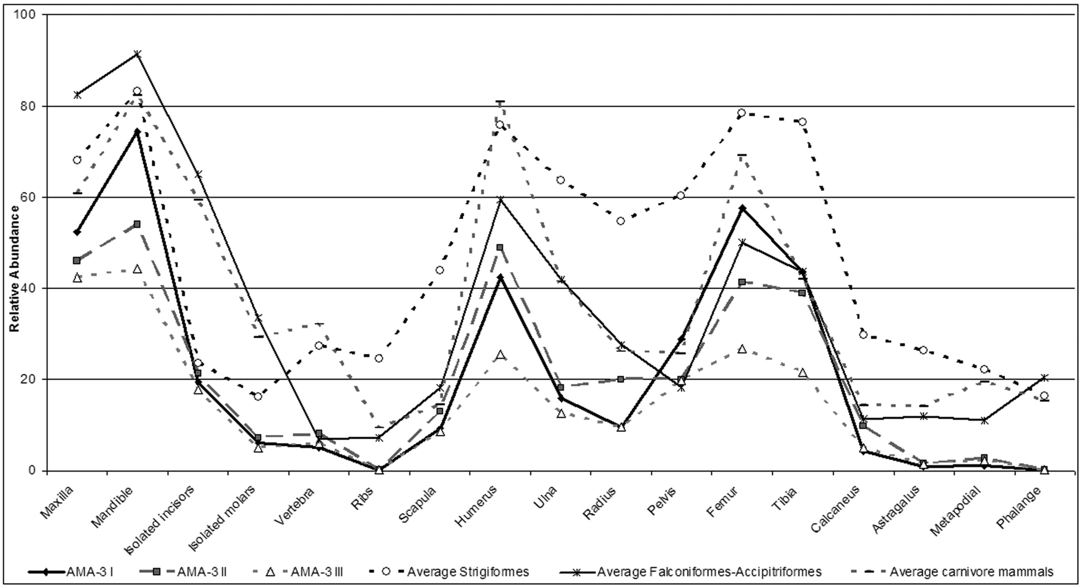

FIGURE 3

Relative abundance values for the various anatomical elements from the units of Arroyo Malo-3, compared with micromammal assemblages generated by average of diferent kind of predators (cf. Andrews, 1990).

The fracture values of postcranial elements in relation to the methodology proposed by Andrews (1990) and Fernández-Jalvo & Andrews (1992) (*i.e.*, femur, humerus, tibia and ulna) was slightly superior to 50% in all units, with the Unit III being the highest (58.9%). Furthermore, a differential preservation of the proximal segments of femurs and ulnae and distal segments of humeri and tibias was observed.

The Unit I exhibited similar rates of fracture surfaces remains with rounded edges and smooth surfaces (50.7%), and sharp edges and rough surfaces (49.3%). Meanwhile, the units II and III had a higher proportion of broken postcranial elements of fracture surfaces with rounded edges and smooth surfaces (73.5% and 74.5%, respectively). Moreover, the vertebrae, calcaneus, astragalus, metapodia and phalanges were found complete in all units. However, the most fragile elements, like scapular and pelvic girdles, showed a high degree of rupture (Table 4). Overall, relevant differences among the units in the various taphonomic indicators were not detected. The few differences which can be observed may be related to stochastic processes and within the range of variation of a fairly uniform process of deposition along the sequence.

The values obtained from the calculated indices are shown in Table 5. The first index that assesses the relationship between cranial and postcranial elements suggests a better preservation of the former in all units while the second index indicates a decline of the postcranial elements in all units. The index that values the relationship between distal and proximal elements of the limbs indicated a predominance of proximal elements in all units. As for the indices of teeth loss it was observed in all units that most of the molars and incisors were retained in the alveoli. SI and PI indices showed a predominance of micromammals of smaller size and solitary and cryptic in all units.

Moreover, it is stressed that, in the three units, remains with cut marks were not found and none of the units exceeded the 0.5% of remains with evidence of thermal alteration. In regard to taphonomic processes, the units I and III showed very low values of weathering (0.2%, corresponding to the stage of weathering II *sensu* Andrews, 1990) and absence in Unit II. Towards the sequence there were no bone specimens with trampling marks or roots. Also, many specimens with manganese oxide impressions were recovered in all units (Unit I = 38.6%; Unit II = 43.8%, Unit III = 35.5%). However, evidence of sedimentary corrosion has

	Unit I		**Unit II**		**Unit III**	
	N	**%**	**N**	**%**	**N**	**%**
Breakage of skulls						
Complete skull	0	0	0	0	0	0
Maxillary with zygomatic	36	7.9	6	4.4	2	1.6
Maxillary without zygomatic	419	92.1	132	95.6	122	98.4
Molars missing from maxillary	383	29.7	153	43.7	84	28.5
Incisors missing from premaxillary	16	30.8	5	33.3	1	25
Breakage of mandible						
Complete mandible	69	10.7	16	9.9	4	3.1
Ascendant ramus broken	221	34.3	57	35.2	42	32.6
Without ascendant ramus	210	32.6	45	27.8	33	25.6
Without ascendant ramus and inferior edge broken	145	22.5	44	27.2	50	38.8
Molars missing from mandible	748	38.9	180	36.2	159	44.2
Incisors missing from mandible	58	11.3	15	12.7	4	6.1
Breakage of teeth						
Broken molars *in situ*	71	3.4	20	3.4	13	3.2
Broken isolated molars	139	43.3	60	45.5	43	49.4
Total broken molars	210	8.7	80	12.4	56	11.2
Broken incisors *in situ*	75	15.3	5	4.4	13	19.7
Broken isolated incisors	233	68.7	96	75	89	86.4
Total broken incisors	308	37.2	101	41.9	102	60.3
Breakage of postcranial elements						
Femur						
Complete	211	42.3	52	41.9	34	43.6
Proximal	276	55.3	67	54	44	56.4
Shaft	5	1	1	0.8	0	0
Distal	7	1.4	4	3.2	0	0
Humerus						
Complete	229	62.2	94	63.9	44	58.7
Proximal	6	1.6	1	0.7	3	4
Shaft	3	0.8	0	0	0	0
Distal	131	35.5	52	35.4	28	37.3
Tibia						
Complete	118	31.1	45	38.5	15	23.8
Proximal	84	22.2	17	14.5	18	28.6
Shaft	30	7.9	14	12	7	11.1
Distal	147	38.8	41	35	23	36.5
Ulna						
Complete	74	53.6	25	45.5	11	29.7
Proximal	64	46.4	30	54.5	25	67.6
Shaft	0	0	0	0	0	0
Distal	0	0	0	0	1	2.7

TABLE 3

Fracturing in cranial, dental, and post-cranial elements for micromammalian species from the Arroyo Malo-3 archaeological site.

	Unit I		**Unit II**		**Unit III**	
	N	**%**	**N**	**%**	**N**	**%**
Vertebra	0	0	0	0	0	0
Ribs	7	33.3	2	50	0	0
Scapula	80	100	39	100	25	100
Radius	12	14.5	18	30	8	28.6
Pelvis	225	89.6	59	98.3	57	98.3
Calcaneus	0	0	0	0	0	0
Astragalus	0	0	0	0	0	0
Metapodial	0	0	0	0	0	0
Phalange	0	0	0	0	0	0

TABLE 4

Fracturing in others post-cranial elements for small mammals from the Arroyo Malo-3 archaeological site.

not been found in any of these. Throughout the sequence there were no bones remains with rounded ends and protrusions of the bones and teeth, indicating that effects of abrasion by water transport, movement and friction of the remains against the sediment did not occur (Korth, 1979; Andrews, 1990; Fernández-Jalvo & Andrews, 2003).

Taxonomic structure and paleoenvironmental analysis

The small mammals recorded at the AMA-3 and their abundances are detailed in Table 6, and Figures 4 and 5B. The AMA-3 sequence is characterized by high frequencies (13-33% of total MNI) of the sigmodontine rodents *Phyllotis xanthopygus* (yellow-rumped pericote), *Euneomys chinchilloides* (Patagonian chincilla mouse) and *Eligmodontia* sp. Followed by the hystricognath rodents *Ctenomys* sp. and *Microcavia autralis* (southern mountain cavy), and the sigmodontine *Abrothrix hirta* (long-haired grass mouse) with lower values (1-11%). These small mammals are recorded throughout the stratigraphical sequence. However, other species such as the sigmodontine *Abrothrix olivacea* (olive grass mouse) and *Chelemys macronyx* (Andean long-clawed mouse) and the didelphid marsupial *Thylamys pallidior* (mouse opossum) had a discontinuous and scarce record. In addition, the didelphid marsupial *Lestodelphys halli* (Patagonian opossum) and the exotic Leporidae are restricted to the Unit I, the former belong to the deeper layer (#12), and the latter to the upper layer (#1).

	Unit I	**Unit II**	**Unit III**
Postcranial / Cranial			
f+t+h+r+u/ mx+mb+m	165.3	186.3	132.2
h+f/ mx+mb	78.9	90.3	60.5
Distal / Proximal elements			
t+r/ f+h	53.2	65.3	59.5
% isolated teeth			
% isolated molars	54.4	64.8	59
% isolated incisors	15.1	17.7	7.6
Size Index (SI)	722.8	816.7	671.4
Predictability Index (PI)	13.8	12.2	14.9

TABLE 5

Values of the indices calculated for the Arroyo Malo-3 archaeological site: f = femur; t = tibia; h = humerus; r = radius; c = ulna; mx = maxilla; mb = mandible; m = molar.

The codominance of *P. xanthopygus*, *E. chinchilloides*, *Eligmodontia* sp., and *Ctenomys* sp. characterizes the three analytical units studied and also the recent assemblages close to the archaeological site. In addition, it is important to note the higher frequencies of *T. pallidior* and *A. olivacea* found in the recent samples (Figure 5B).

The topographic and environmental diversity from Southern Mendoza province involves deep changes over relatively short distances in the small mammal taxonomic structure (Fernández, 2012a). Among this diversity it is included the high Andean Cordillera westward, a foothill fringe extending along the Andes, a large plain (lowland) eastward, and the extensive volcanic field of Payunia southward. The Figure 5A shows –schematically– the distribution of micromammal taxa along the west-east altitude gradient considering the 16 studied raptor pellet samples.

The multivariate analysis –including PCA and cluster (Figure 6)– grouped the recent samples by phytogeographic affiliation, and not by raptor especies, suggesting their condition as good estimators of small mammal communities. Moreover, the multivariate analysis located AMA-3 archaeological assemblages close to the recent raptor samples of Patagonian steppe located >1200 m asl, even the recent samples collected in the site and 1 km from there (*i.e.*, Arroyo Malo and Laguna El Sosneado), and separated from those associated with Monte desert located in the plain, mainly composed by the sigmodontine *Graomys griseoflavus*

Chronology (ka ^{14}C BP)	**0.1-2.2**			**2.2-3.8**			**3.8-8.9**		
	Unit I			**Unit II**			**Unit III**		
	NISP	**MNE**	**MNI**	**NISP**	**MNE**	**MNI**	**NISP**	**MNE**	**MNI**
Mammalia									
Didelphimorphia									
Thylamys pallidior	2	2	1	0	0	0	1	1	1
Lestodelphys halli	1	1	1	0	0	0	0	0	0
Rodentia									
Ctenomyidae									
Ctenomys sp.	108	108	44	22	22	15	25	25	16
Caviidae									
Microcavia australis	18	18	12	3	3	3	7	7	5
Cricetidae / Sigmodontinae indet.*	3284	3267		1374	1363		887	887	
Abrothrix olivacea	82	82	38	9	9	4	0	0	0
Abrothrix hirta	9	9	5	5	5	4	3	3	3
Chelemys macronyx	4	4	3	0	0	0	1	1	1
Phyllotis xanthopygus	378	378	132	103	103	45	96	96	48
Eligmodontia sp.	131	131	59	62	62	33	69	69	35
Euneomys chinchilloides	390	390	138	92	92	46	72	72	37
Lagomorpha / Leporidae indet.	1	1	1	0	0	0	0	0	0
Total	4408	4391	434	1670	1659	150	1161	1161	146

TABLE 6

Taxonomic composition of the micromammal samples from the Arroyo Malo-3 (quadrat B-1) archaeological site (expressed NISP, MNE, MNI). * Only postcraneal elements, possibly corresponding to identified taxa.

(gray leaf-eared mouse), *Akodon dolores* (Dolorous grass mouse), *Calomys musculinus* (drylands vesper mouse), *Oligoryzomys flavescens* (yellow pygmy rice rat) and the hystricognath *Galea leucoblephara* (yellow-toothed cavy) (see also Figure 5A). In addition, the difference with other Patagonian samples, for example 6 km S of Las Leñas and Laguna de la Niña Encantada, could be explained by the high occurrence of the sigmodontine *Euneomys mordax* (biting chincilla mouse) and *Loxodontomys micropus* (southern pericote), associated with the higher elevation areas (see also Figure 5A) with soils under mesic conditions (Pardiñas *et al*., 2008; Fernández *et al*., 2009b). Even La Pasarela, a recent sample characterized by low frequence of *E. chinchilloides* (< 3%), and the presence of the sigmodontine *Oligoryzomys longicaudatus* (long-tailed pygmy rice rat) allied with bushy and mesic areas (Pardiñas *et al*., 2003, 2008, 2011).

DISCUSSION

Taphonomic interpretation

Among the main taphonomic results obtained by Neme *et al*. (2002) in their study of materials from the quadrat A-1, it was indicated that no evidence of postdepositional processes were found and that strigiforms were the main accumulator of the small mammal remains; but without detailed reference on which and how many remains were affected by taphonomic processes characteristic of these birds. However, this study, conducted from micromammal samples recovered from the quadrat B-1, showed different evidence. The discovery of fragments of pellets, bones with remains of pellets, high levels of corrosion fracture digestive and mostly with rounded ends and soft edges, the low average relative abundance, and relative

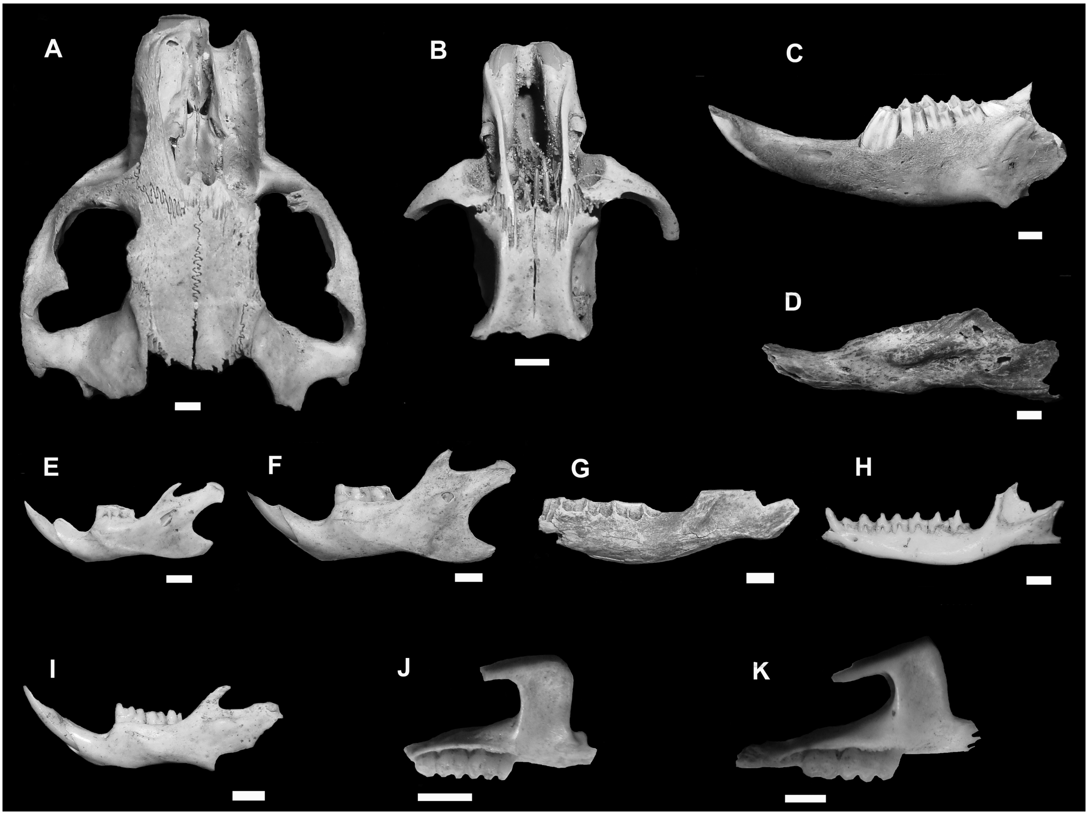

FIGURE 4

Small mammals recovered at Arroyo Malo 3. A. *Ctenomys* sp., skull in dorsal view (Layer 29, Unit III); B. *Euneomys chinchilloides*, skull in dorsal view (Layer 17, Unit II); C. Leporidae indet., mandible in labial view (Layer 1, Unit I); D. *Microcavia australis*, mandible in labial view (Layer 6, Unit I); E. *Eligmodontia* sp., mandible in labial view (Layer 7, Unit I); F. *Phyllotis xanthopygus*, mandible in labial view (Layer 9, Unit I); G. *Lestodelphys halli*, mandible in labial view (Layer 12, Unit I); H. *Thylamys pallidior*, mandible in labial view (Layer 3, Unit I); I. *Abrothrix hirta*, mandible in labial view (Level 1, Unit I); J. *Abrothrix olivacea*, maxillary in lateral view (Layer 1, Unit I); K. *Chelemys macronyx*, maxillary in lateral view (Layer 1, Unit I). Scales = 2mm.

abundance pattern of skeletal parts in all units show an agreement with the studies of Andrews (1990) based on recovered remains of pellets from Accipitriformes and Falconiformes. Considering the species of this diurnal birds of prey present in the area, the taphonomic studies conducted by Andrews (1990) suggest that *F. peregrinus* produces moderate changes in micromammal assemblages and can not be considered a major accumulator of this kind of mammals as it mainly consumes medium-sized birds. Also, although there is no taphonomic information, the predatory activity of *F. sparverius*, focused mainly on insects and, to a lesser extent, mammals, birds and reptiles (*e.g.*, Sarasola *et al.*, 2003) suggests a low probability as an accumulator in the assemblages of AMA-3. Furthermore, the taphonomic analysis performed by Iglesias (2009) on *B. polyosoma* and Montalvo & Tallade (2009) in *C. plancus* showed that these birds produce high levels of modification in the remains of the eaten mammals. However, Montalvo & Tallade (2009, 2010) reported a low level of modification in mammal remains uneaten by *C. plancus*. Nevertheless, of the raptors mentioned only *B. polyosoma* and *G. melanoleucus*, besides nesting in rockshelters, consume mainly small mammals (*e.g.*, White *et al.*, 1994, and references therein). Also, although there is no published work on taphonomy of *G. melanoleucus*, one of the samples studied in this work and collected in the rockshelter of AMA-3 (cf. Arroyo Malo recent sample) showed that the remains of

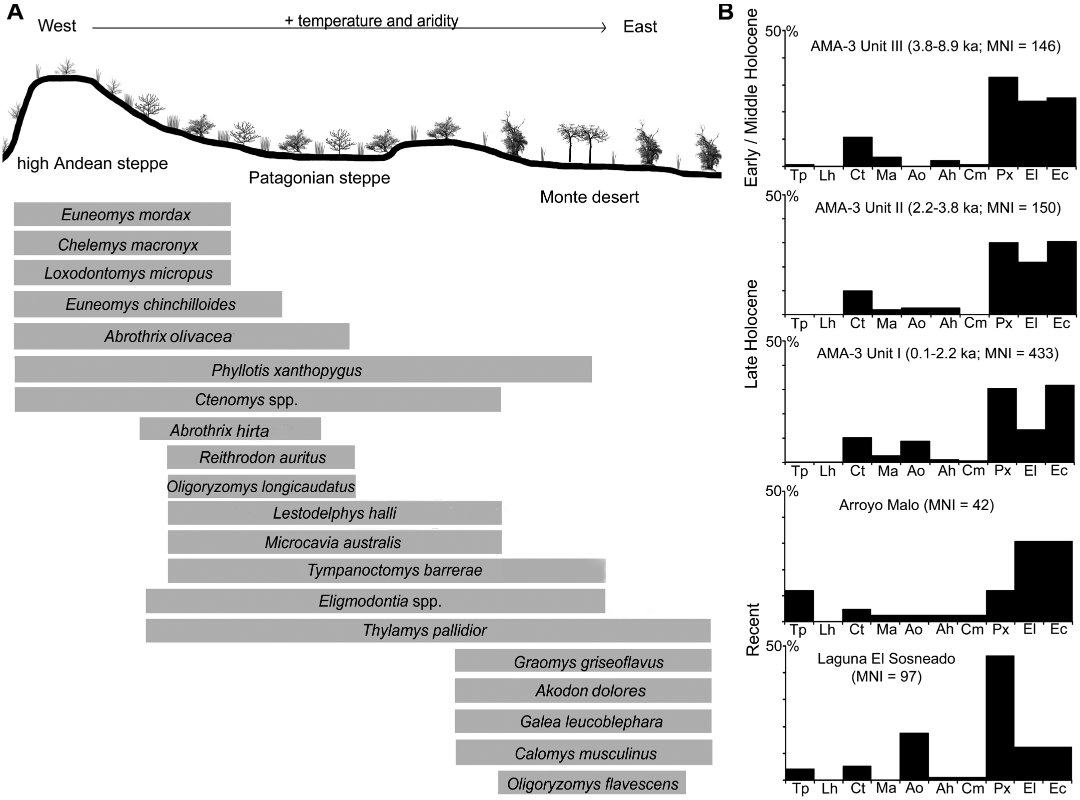

FIGURE 5

A. Distribution of micromammalian taxa in a west-east gradient in Central South of Mendoza Province, based on the 16 raptor pellet samples; B. Histograms showing the small mammal abundance (expressed as percentage of the minimum number of individuals [MNI]) of archaeological samples and two recent samples closest to Arroyo Malo-3. Abbreviations: *Thylamys pallidior* (Tp); *Lestodelphys halli* (Lh); *Ctenomys* spp. (Ct); *Microcavia australis* (Ma); *Abrothrix olivacea* (Ao); *Abrothrix hirta* (Ah); *Chelemys macronyx* (Cm); *Phyllotis xanthopygus* (Px); *Eligmodontia* spp. (El); *Euneomys chinchilloides* (Ec).

small mammals had moderate and strong values of corrosion and fracture. In this sense, it is suggested that *B. polyosoma* or *G. melanoleucus* could be the main store agents of small mammals of AMA-3. In addition, the taxonomic structure recorded in AMA-3 assemblages is similar to the recent pellet samples of *B. polyosoma* and *G. melanoleucus* used here (see Fernández, 2012a: 328, 352, respectively), and to samples of these raptors from other regions of Argentina (Bó *et al.*, 2007, and references therein). This ensures an adequate comparison with the recent raptor pellet samples, in order to carry out paleo-environmental interpretations (*e.g.*, Andrews, 1990, 1995).

On the other hand, the absence of cut-marks, presence of few burned remains, and very low abundance of some large, mostly diurnal, gregarious or colonial rodents recovered from the units of AMA-3 site would indicate non-human deposition (cf. Pardiñas, 1999a, 1999b).

In agreement, the studies made in the south of Mendoza and north of Neuquén show the low participation of humans in the formation of small-mammal assemblages, but rather showed a majority participation of birds of prey (Gasco *et al.*, 2006; Fernández, 2010, 2012a; Fernández *et al.*, 2011a, 2012). Only human action has been proven in one of the units of the Cueva Arroyo Colorado site (35°12’10.65”S, 70º04’38.91”W, Unit I), by finding cut-marks on rodents hystricognath remains to *ca.* 1400 ^{14}C BP (Fernández *et al.*, 2009a; Fernández, 2012a).

Finally, the low record of weathered bones suggests that they had a quick burial. This, added to the absence of trampling marks, roots, corrosion

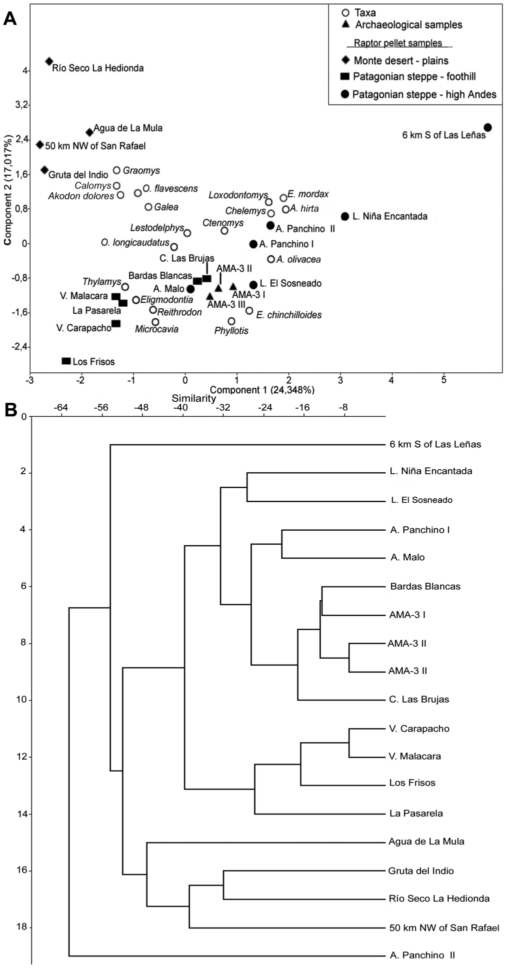

FIGURE 6

Multivariate analyses of archaeological small mammal samples of Arroyo Malo-3 (AMA-3) and recent raptor pellet samples from Central South of Mendoza province. A. Principal component analysis; B. Cluster analysis (ccc = 0.899).

and water transport sediment, suggests that the remains had a high postdepositional integrity (Korth, 1979; Andrews, 1990; Fernández-Jalvo & Andrews, 2003). However, the many specimens with manganese oxide impressions in all the units suggest high levels of humidity, due to fluctuations in the water table (Gómez *et al.*, 1999).

Paleoenvironments interpretation

The Table 7 shows the small mammal assemblages documented by Neme *et al.*, (2002). Given the finding of an *Andalgalomys* sp. (chaco mouse) remain at the beginning of the sequence (*ca*. 8900 years ^{14}C BP), a genus of sigmodontine rodent that in Argentina only has one species (*A. olroigi*) inhabiting arid areas in the centre and northwest of the country (*e.g*., Mares & Braun, 1996), suggested a paleoenvironmental scenario warmer and drier than the current times (Neme *et al*., 2002). Furthermore, in the period after 4000 years ^{14}C BP, the record of *L. halli* was related to a Patagonian environment similar to the present (Neme *et al*., 2002). Finally, the presence of *G. griseoflavus* and *M. australis* in the same temporal segment was linked to over-exploitation of the environment by humans through overgrazing (Neme *et al*., 2002). A detailed review of the sample indicated that the specimens assigned to *Abrothrix* sp. correspond to *A. hirta* and *A. olivacea*. Likewise, those referred to *E. mordax* correspond to *E. chinchilloides* and those identified as *G. griseoflavus* and *Andalgalomys* sp. correspond to *P. xanthopygus*. For the case of *Andalgalomys* sp. a detailed description was made due to its high level of relevance in the paleoenvironmental interpretation. The referred material is an incomplete right maxilla with M2 and M3 (Figure 7A). Molars have flat wear and opposite cusps. The M2 is subcuadrangular with reduced paraflexus, mesoflexus obliquely oriented and hipoflexus transversely pierced. In the M3, the confluence of mesoflexus and hipoflexus determines two lobes, the upper lobe slightly more

Chronology (ka ^{14}C BP)	**2.2**	**3.8**	**8.9**
	Unit I	**Unit II**	**Unit III**
Mammalia			
Didelphimorphia			
Lestodelphys halli	1	1	0
Rodentia			
Ctenomyidae			
Ctenomys sp.	31	19	7
Caviidae			
Microcavia australis	7	2	1
Cricetidae / Sigmodontinae indet.	17	12	2
Abrothrix sp.	40	13	0
Phyllotis darwini (= *P. xanthopygus*)	128	49	31
Graomys griseoflavus	3	0	0
Andalgalomys sp.	0	0	1
Eligmodontia sp.	32	29	11
Euneomys cf. *E. mordax*	109	47	25
Total	368	172	78

TABLE 7

Taxonomic composition of the small mammal samples from Arroyo Malo-3 (quadrat A-1) archaeological site (expressed NISP) analyzed by Neme *et al*. (2002: 412).

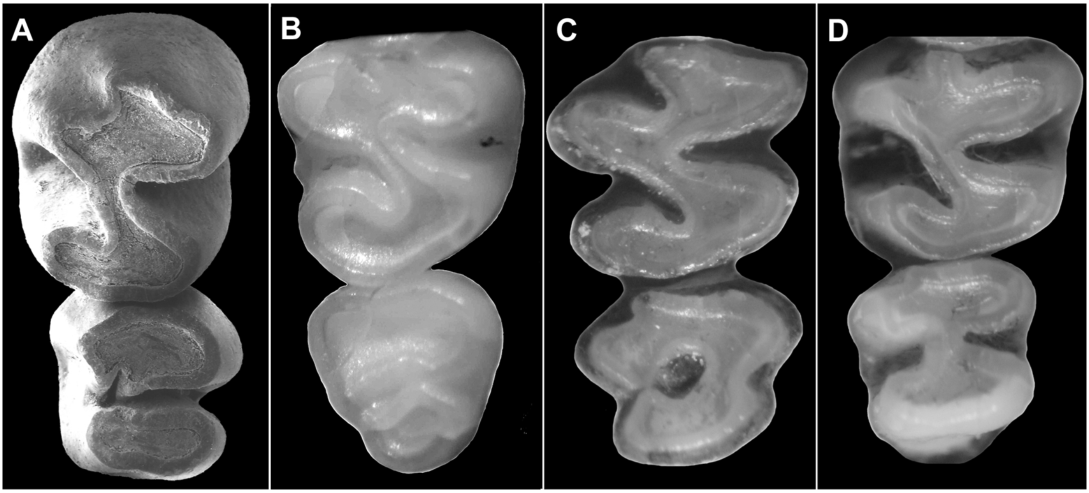

FIGURE 7

Comparison of upper molar toothrows in oclussal view related to the taxonomic determination of *Andalgalomys* sp. from Arroyo Malo-3 (quadrat A-1). A. Specimen of Arroyo Malo-3 (M1-M2 length: 2.9 mm); B. *Andalgalomys olroigi* (M1-M2 length: 3.2 mm); C. *Graomys griseoflavus* (M1-M2 length: 2.82 mm); D. Juvenile individual of *Phyllotis xanthopygus* (M1-M2 length: 2.72 mm).

developed than the lower one. Similar morphology of M2 can be found in both adult individuals of *A. olroigi*, as in senile individuals of *Graomys* and juveniles of *Phyllotis*. Furthermore, these taxa exhibit two well marked lobes in M3. *A. olroigi* presents the lower lobe very small compared to the upper one (Figure 7B). In *Graomys*, the lobes have a more oblique orientation and cusps are more tubercular (Figure 7C). In *Phyllotis* (mostly juveniles) the upper lobe shows a slightly larger size than the lower one (Figure 7D), in coincidence with the described material. In this sense, it is suggested that the maxilla fragment assigned by Neme *et al*. (2002) to *Andalgalomys* sp. corresponds to a juvenile of *P. xanthopygus*.

In this sense, these paleoenvironmental interpretations will be reassessed in the light of new findings of numerous materials recovered in quadrat B-1, and will be discussed with other small mammals records (even molecular data), and other available paleoenvironmental *proxies* (*i.e*., glaciological, sedimentological, geomorphological, palynological and dendrological). Although still remains a gap in knowledge, there are valuable paleoclimatic and paleoenvironmental researches conducted in areas near the location of AMA-3, including upper basin of river systems of Atuel, Salado and Grande (see the rivers location in Figure 1 [above]).

Taken into account the glaciological information, in the upper basin of the Atuel river there was a marked glacier decline towards the transition to the Late Pleistocene-Early Holocene (from 13,000 to 8000 years ^{14}C BP) (Stingl & Garleff, 1985). Towards the Mid-Holocene glacial readvances were recorded (6000 and 4500 ^{14}C BP), associated with colder and moister conditions (Stingl & Garleff, 1985). About 3000 years ^{14}C BP a rapid glacier regression was detected, when the glaciers reached their current position and then advance between the 19th and 20th centuries (Stingl & Garleff, 1985). In the upper basin of Grande river, glacier readvances were recorded between 5700-4400 years ^{14}C BP, 2500-2200 ^{14}C BP and *ca*. 400 years ^{14}C BP, the latter linked to the Little Ice Age (Espizua, 2005).

Navarro *et al*. (2010) conducted sedimentological, palynological and geomorphological studies in sites located in the surrounding area of AMA-3. From the record of peat deposits of Agua Buena profile it is indicated the development of meadows and more stable conditions between *ca*. 4100-2800 years cal BP. After *ca*. 2800 years cal BP, they noted lower water availability for the development of cordilleran meadows. From the middle section of the Vega de la Cueva profile, a humid microenvironment has been indicated between *ca*. 3800-1400 years cal BP. Data from Laguna El Sosneado revealed a high combustion of wood and the development of a Patagonian steppe between the Mid and Late Holocene (*ca*. 6400-1900 years cal BP), indicating more humid and cold conditions than the present. Between *ca*. 1900-500 years cal BP, conditions were drier and warmer, and a scarce fire activity was recorded, indicated by increases in sparse vegetation of the Monte-Patagonian ecotone type. From *ca*. 500 years cal BP, the transition environment continues between Monte and Patagonian steppe, showing a slight increase in humidity and the establishment of modern environmental conditions (Navarro & Whitlock, 2010; Navarro *et al*., 2010). Furthermore, the pollen records of the Agua Buena locality were globally interpreted by Paez *et al*. (2010) as an environment similar to the current at the beginning of the Late Holocene and with an increment of water availability in river systems, possibly under the influence of ENSO (El Niño Southern Oscillation) towards *ca*. 2800 years cal BP. In the upper basin of Salado river *ca*. 3000 years ^{14}C BP, the presence of pollen elements more diverse towards a transition zone, an increase in temperature and environmental conditions similar to the present were recorded (Markgraf, 1983).

Moreover, Boninsegna & Delgado de Brun (2002) studied the variations in flow Atuel River since 1575 to the present, analyzing the tree rings. The authors noted that the river level increases with the increment of the amount of snow in the upper basin, which could be related to the influence of the interannual ENSO event.

Before returning to the small mammal records of the study area, it is interesting to note that recent phylogeographic studies with molecular markers indicate for southern Mendoza and northern Neuquén, a refuge area for several species of sigmodontine rodents such as *A. olivacea*, *A. hirta*, *C. macronyx*, *L. micropus* and *P. xanthopygus*, genetically different from southern Patagonian populations (Cañón *et al*., 2010; Lessa *et al*., 2010; Abud, 2011; Alarcón *et al*., 2011; Riberón, 2011). According to these authors, the populations of these species expanded southward to reach the current distribution range, posterior to The Last Glacial Maximum (LGM) *ca*. 24,000 to 18,000 years BP. Also, populations with shelters in the north of Neuquén and Mendoza were more stable and the ones in higher latitudes were possibly more susceptible to climatic changes related to the cycles of the Neogene (Lessa *et al*., 2010). These phylogeographic evidences could be indicating that the area involving the north of Neuquén and south of Mendoza were not that affected by glacial retraction, so that changes in the genetic structure of populations of some species of sigmodontine occurred, as it did occurred in southernmost populations (Lessa *et al*., 2010).

The AMA-3 micromammalian record was compared with recent samples collected around the site. Its show that the dominance of *P. xanthopygus*, *E. chinchilloides*, *Eligmodontia* sp. and *Ctenomys* sp. have remained basically unchanged, suggesting the development of shrubby steppes, open bare areas and large rocky outcrops during the Early Holocene up to recent times (Pardiñas *et al*., 2003, 2011). In addition, the *A. hirta* and *C. macronyx* records indicate the development of mesic soil (cordilleran meadows) in a semiarid matrix of the Patagonian steppe (Pardiñas *et al*., 2003, 2011).

About 150 km east of AMA-3, recent small mammal assemblages are mainly composed by species associated with Monte desert (*i.e*., *C. musculinus*, *G. griseoflavus*, *A. dolores*, *G. leucoblephara*). These species never reached the AMA-3 area, an expectable situation if warmer and drier events had a major environmental impact on the taxonomic structure of small mammal assemblages, as it was pointed out by Neme *et al*. (2002) based on the occurrence of *Andalgalomys* sp.

The northern distribution of *L. halli* corresponds to Mendoza province and it was not found at altitudes >1800 m. In this sense, the presence of this marsupial in the Unit I (Layer 12) suggests a more heterogeneous environment and a rise in ecological levels towards the 2200 BP. In a broad view, *L. halli* is restricted to the Patagonian steppe. The finding of this marsupial in Monte desert (*e.g*., 50 km NW of San Rafael recent sample) is considered a relict of those that were more widely distributed in the Late Holocene, and could not represent the optimal habitats where this species inhabits today (*e.g*., Udrizar Sauthier *et al*., 2007). Moreover, in the local resent sample the increased frequency of *T. pallidior* to the detriment of *E. chinchilloides* could be associated with the passage of herbaceous plants to shrubs. Coincidentally, the absence of the opportunistic abrotriquine *A. olivacea* in Unit III, its presence in the Unit II, the incremented frequency in the Unit I could be linked to a gradual increase of shrubs in the environment. In the Patagonian region, the influence of sheep (from the late 18th century), the extensive cultivated fields (since the 19th century), the possible alterations of the burning regimes, desertification and introduction of exotic species of animals and plants, produced significant changes in recent small mammal communities and the increase of opportunistic species over the others (Pardiñas *et al.*, 2000, 2011, 2012). Both in the west of Patagonia and along the Río Santa Cruz, the opportunistic abrotriquine *A. olivacea* exhibited an increment of its frequency in current assemblages (*e.g.*, Pearson, 1983; Teta *et al.*, 2005; Cueto *et al.*, 2008; Pardiñas *et al.*, 2011; Pardiñas & Teta, 2013). Also, the abrupt decrease of *Euneomys* spp. in current assemblages in some parts of the northwest of Patagonia, after *ca.* 10.000 years of dominance was associated with a process of increase of shrubs (Pearson, 1987; Pearson & Pearson, 1993; Pardiñas, 1999a; Pardiñas *et al.*, 2011; Pardiñas & Teta, 2013). In two archaeological sites near AMA-3 (*i.e.*, Cueva Arroyo Colorado and Caverna de Las Brujas [35º45'S, 69º49'W]) *A. olivacea* was not recorded in the sequences, however, was one of the dominant species present in the local current assemblages (*i.e.*, 6 km S. of Las Leñas and Caverna de Las Brujas) (Gasco *et al.*, 2006; Fernández *et al.*, 2009a). In this sense, this type of human impact on the environment may occured in the south of Mendoza, mainly associated with the livestock of goats (*Capra hircus*) consolidated in the region since the 19th century (Gil *et al.*, 2006), causing the over-exploitation of vegetation, an increase in bare soil and a restructuration of the current small mammal communities. In addition, in southern Mendoza two species of Leporidae, *Lepus europaeus* (European hare), by the end of the 19th century, and *Oryctolagus cuniculus* (European rabbit), in the second half of the 20th century (Bonino, 2006; Novillo & Ojeda, 2008), were introduced. These species have a broad diet, high reproduction rate and high dispersal capacity, producing a strong impact on soil, vegetation and native fauna, especially in their ecological equivalents (Novillo & Ojeda, 2008). In this sense, the record of an indeterminate leporid in Unit I (Layer 1) would indicate the belonging of this layer to posterior chronologies after the 19th century and it is also consistent with the progressive shrubs process above described.

The general small mammal stability of AMA-3 can be explained by two alternative but non-exclusive hypotheses:

(1) The Holocene climate pulses in southern Mendoza were not severe enough to produce deep modifications in the taxonomic structures of small mammal communities close to AMA-3. According to the paleoenvironmental studies only the Mid-Holocene suffered a major climate change (see above). Although the time intervals in the defined units of AMA-3 the Mid-Holocene was not considered, the layer 23 had a dating *ca.* 5400 years ^{14}C BP, with a little heterogeneous assemblage composed by *Ctenomys* sp., *P. xanthopygus*, *E. chinchilloides*, *Eligmodontia* sp. and *A. hirta*. Similiar tendency was reported in Caverna de Las Brujas sequence between 5000 years TL BP-3800 years ^{14}C BP (Gasco *et al.*, 2006). On the other hand, the Early and Late Holocene had a stable climate, although in the last period some fluctuations (wetter and drier) were recorded mainly associated with ENSO events (see above). Likewise, the AMA-3 micromammalian samples have some taxonomic variations mainly during Late Holocene, associated to wet and dry pulses. In congruence, in the upper basin of Salado, small mammal assemblages from Cueva Arroyo Colorado archaeological site showed a marked taxonomic stability during the Late Holocene, although slight changes across the sequence. These are related to an environment of open shrub steppes with a high proportion of stony bare soil, plenty of exposed rock and cordilleran meadows, from 3190 years ^{14}C BP (3429 years cal BP) to the present, with a slight variation for the interval 1380-770 years ^{14}C BP (1294-728 years cal BP) (Unit I), where there was greater water availability (Fernández *et al.*, 2009a; Fernández, 2012a).

(2) The small mammal communities of Patagonian steppe and high Andes cordilleran of southern Mendoza were highly resilient to paleoenvironmental changes. This hypothesis could be related to phylogeographic studies, which showed no major genetic variations in several sigmodontine rodents since the LGM (see above). In coincidence, several small mammal assemblages in northern Patagonian archaeological sites, remain stable from Pleistocene-Holocene transition to the Late Holocene (*e.g.*, Pearson, 1987; Pearson & Pearson, 1993; Pardiñas, 1999a; Teta *et al.*, 2005; Fernández *et al.*, 2009a, 2011a, 2012; Pardiñas *et al.*, 2011; Fernández, 2012a; Pardiñas & Teta, 2013).

Human occupation and intensification at southwestern Mendoza province

The different taphonomic and paleoenvironmental characteristics observed by the record of small mammals recovered from AMA-3, together with archaeological and paleoenvironmental information from other sources can be a contribution to a better understanding of the survival systems and the occupational dynamics of the hunter-gatherer groups who inhabited the region. Neme (2002, 2007) use the biogeographical model of Borrero (1994-1995) to describe the stages of settlement in the cordilleran area. Neme (2002, 2007) indicate that after the retreat of glaciers to the end the Late Pleistocene (*ca*. 14,000 to 10,000 years BP), the areas below 3000 m. altitude would have been favourable places for the establishment of human groups. However, the first human occupation were recorded in the Early Holocene *ca*. 8900 years ^{14}C BP –in the AMA-3 site– where there was a time continuity, high deposition rates and density of cultural remains recovered at lower levels of the site, suggesting that it would have given the stage of colonization of the area (Neme, 2002, 2007). According to the AMA-3 micromammalian record, and others *proxies* (*i.e*., glaciological, sedimentological, palynological and geomorphological) the stage of colonization was established in a paleoenvironmental framework similar to the recent times, with the development of open steppes, meadows, and bare and rocky outcrops. Also, this site is at a strategic level between the foothills and high mountain range, with a broad view of the upper valley of the Atuel river, with access to water, lithic, plant and animal sources, suggesting the selection of optimal locations within the regional landscape by human groups (Neme, 2002, 2007). This author concludes that the strategies used by hunter-gatherers would be characterized by high mobility, with special tasks such as hunting –mainly of *Lama guanicoe* (guanaco)– and supply of raw materials (Neme, 2002, 2007). Human occupations in AMA-3 continue during the Mid-Holocene, albeit with a gap between 7000-5400 years ^{14}C BP (Diéguez & Neme, 2003). However, Gil *et al*., (2005) noted that the Mid-Holocene archaeological gap was not as marked as in the cordilleran range in the eastern plains of Mendoza. For their part, Navarro & Whitlock (2010) suggest that in this period the upper basin of the Atuel (Laguna El Sosneado) presents wetter environment, so the archaeological gap could indicate low dispersed populations, high mobility or poor preservation of the sites, rather than a regional abandonment. The archaeological record during the small part of the Mid-Holocene which took place in AMA-3 is characterized by a predominance of local lithic raw materials and the exploitation of *L. guanicoe*. Although it does not present major changes from the Early Holocene, it shows an increase in mobility, lower intensity of occupation and a change in the use of raw materials (Neme, 2007; Pérez Winter 2009b, 2010). This was understood as a persistence of the colonization stage (Neme, 2007) or re-exploration of the area (Pérez Winter, 2009b, 2010). At the begging of the Late Holocene (4000-2000 years BP), in a framework of environmental stability as was sustained from the small mammal record of AMA-3 (Unit II) and Cueva Arroyo Colorado (Unit II) and other paleoenvironmental *proxies* such as palynological, glaciological, and sedimentological analysis (Markgraf, 1983; Stingl & Garleff, 1985; Fernández *et al*., 2009a; Paez *et al*., 2010; Fernández, 2012a) many valleys were populated, except those with higher levels of risk to human activity (*i.e*., cordilleran valleys > 3000 m asl). For this period, there is an effective occupation of the cordilleran area of and the consumption of *L. guanicoe* as main resource and the use of local raw materials are kept, although there is a higher quantity of grinding elements such as grinding mills and hands (Neme, 2002, 2007). By the end of the Late Holocene (2000-100 years BP), all the cordilleran environments would be occupied, possibly in a context of paleoenvironmental stability, albeit with some wet and dry pulses, possibly associated with ENSO events, which could provide a greater environmental variability for the establishment of human occupations, as it was observed in the record of small mammals of AMA-3 (Unit I) and Cueva Arroyo Colorado (Unit I) and other *proxies* such as palynological, dendrological and glaciological of the area (Boninsegna & Delgado Brun, 2002; Espizua, 2005; Fernández *et al*., 2009a; Navarro *et al*., 2010; Paez *et al*., 2010; Fernández, 2012a). During this period it appears the use of ceramic technology, use of non local raw materials (obsidian and silicate), the manufacture and repair of instruments, and the increase of grinding elements, which besides corroborating the processing vegetable remains, may indicate a higher recurrence to the site and an extension of trading systems at regional level (Neme, 2002, 2007; Pérez Winter, 2009a, 2009b, 2010; Llano, 2008). Also the spectrum of exploited resources is extended, including plants and animals of medium size, which was understood as an intensification process (Neme, 2002, 2007; Llano, 2008). This intensification process has been defined as the consequence of an imbalance between environmental carrying capacity and human demography (Neme, 2002, 2007). Human over-exploitation reduced the availability of highly-ranked resources (*e.g.*, *L. guanicoe*), and change the subsistence towards the inclusion of lowly-ranked resources such as some plants (*e.g.*, *Chenopodium papulosum* [goosefoot], *Schinus polygamus* [hardee peppertree]) and medium mammals (*e.g.*, *Lagidium vizcacia* [southern mountain viscacha], *Chaetophractus villosus* [large hairy armadillo]), with lower caloric returns and higher processing costs (Neme, 2002, 2007; Llano, 2008). In addition, the Unit I presents the greatest taxonomic diversity, including introduced domestic fauna (Caprinae indet.), and the high levels of fracture, cut marks, could indicate human activity through the intake of bone marrow (Neme, 2002, 2007).

However, the taphonomic results of small mammal assemblages of AMA-3 and other sites in southern Mendoza like Laguna El Sosneado-3, Cueva Palulo and Caverna de las Brujas in the cordilleran area, and Agua de La Mula and Agua de Los Caballos-1 in the eastern plains (Gasco *et al.*, 2006; Fernández, 2010, 2012a, 2012b) suggest that this process of intensification would not have been sufficiently marked to exploit small mammals in a systematic way because evidence of use was only recovered at the site Cueva Arroyo Colorado (Unit I, Fernández *et al.*, 2009a; Fernández, 2012a). In agreement, Giardina (2010) based on the findings digestive corrosion evidences in the small birds assemblage recovered from AMA-3, suggests that these could have been accumulated by the action of raptors.

CONCLUSIONS

The taphonomic evidence indicates that the main accumulator of the small mammal assemblages recovered from the units of AMA-3 would have been Accipitriformes, possibly *G. melanoleucus* or *B. polyosoma*. The scarce record of weathered bones, the absence of trampling marks, roots, sediment corrosion and water transport and the discovery of numerous specimens with manganese oxide impressions suggest that the remains had a rapid burial and good preservation; although with high moisture levels, resulting from fluctuations in the water table and ponding of water in the entire sequence. The small mammal assemblages of AMA-3 showed a considerable stability throughout the whole sequence, with some minor changes towards the Late Holocene, possibly associated with ENSO events, as observed in other paleoenvironmental investigations. The major changes occurred in the current assemblages close to the site, marked by increase of shrubs attributable to human impact possibly produced by domestic livestock reinforced in the south of Mendoza since the 19th century. The paleoenvironmental and taphonomical information presented along with previous researches provide a relevant framework to improve archaeological studies of the biogeography and subsistence system of southern Mendoza hunter-gatherer populations through the Holocene. In summary, the first human occupation of the cordilleran region of the upper valley of the Atuel river were recorded at the beginning of the Early Holocene in the site AMA-3 (*ca*. 8900 years ^{14}C BP) in a paleoenvironmental framework that is similar to the current. The occupations in AMA-3 continue during the Mid-Holocene, albeit with a gap between 7000-5400 years ^{14}C BP possibly associated with a paleoclimatic event of regional cold and humity. At the beginning of the Late Holocene (4000-2000 years BP), in a framework of environmental stability, there is an effective occupation of the cordilleran area in AMA-3 and in several archaeological sites. By the end of the Late Holocene (2000-100 years BP), possibly in a context of paleoenvironmental stability, albeit with some wet and dry pulses, possibly associated with ENSO events, an important change in human subsistence occurs, covering a wider range of exploited resource. However, this process of intensification of resources would not have been sufficiently marked to exploit small mammals in a systematic way.

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