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Anthropogenic modifications to archaeological human bones from the lower Paraná River basin (Argentina)

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ABSTRACT

Late Holocene hunter-gatherers from the lower Paraná River basin presented complex mortuary practices, among other cultural aspects. Recent archaeological excavations in the region have brought to light new evidence about postmortem anthropogenic modifications to human bones that allows us to discuss a relatively unexplored social aspect associated with funerary practices, namely, human corpse manipulation. In this work, we present and discuss postmortem anthropogenic modifications to human bones from five archaeological sites, including tool marks, thermal alteration and bone artifacts. The results show that this evidence is related to, on one hand, the preparation of secondary burials, which in some cases implied disarticulating and/or defleshing the body, and, on the other hand, a possible ancestor cult evidenced through using human bones as a raw material for making bone tools. In addition, the lack of differences between the archaeological sites regarding mortuary practices in general and the abovementioned evidence in particular does not allow us to establish local differences based on a specific mortuary pattern. Instead, similarities between these practices suggest that the societies inhabiting the region shared the same cultural background.

1. Introduction

Cultural modifications to bones may be a consequence of different human activities related to carcass-processing behaviors, mortuary practices, technology, cannibalism, and inter- and intragroup violence. Under these circumstances, bones experience a series of peri- or postmortem modifications and/or alterations, such as impact fractures, perforations, cut marks, thermal alterations (e.g. Bello et al., 2016; Fernández-Jalvo et al., 1999; Haverkort and Lubell, 1999; Larsen, 1997; Larsson, 1984; Valera et al., 2014; Villa et al., 1986; White, 1992), and changes related to preform acquisition and the manufacture of bone tools with utilitarian and symbolic purposes (e.g. Acosta et al., 2011a; Cid and Romano, 1997; Hester, 1969; Meza, 2008, 2015; Rojas et al., 2004; Verna and d'Errico, 2011).

The aim of this paper is to provide new evidence and interpretations about human corpse manipulation among late Holocene hunter-gatherers inhabiting the lower Paraná River basin (Argentina). To this end, we examined postmortem anthropogenic modifications to human bones, including tool marks, evidence of thermoalteration and bone artifacts. The human remains come from five archaeological sites (Las Ánimas, Cerro Lutz, Cerro Mayor, Escuela 31 and Túmulo 1 del Brazo Largo; Fig. 1) from the last 1800 years ^{14}C BP.

Studies on mortuary practices from hunter-gatherer societies in the region have revealed the existence of a significant quantity, variability and complexity of human burials, which implied corpse manipulation (Acosta and Mazza, 2016; Caggiano, 1984; Gaspary, 1950; Gatto, 1939; González, 1947; Greslebin, 1931; Loponte, 2008; Lothrop, 1932; Mazza and Loponte, 2012; Petrocelli, 1975; Scabuzzo et al., 2015; Torres, 1911; Zeballos and Pico, 1878). However, several funerary aspects remain relatively unknown; these are cases of secondary burials with cut marks, the presence of thermally altered bone fragments or complete anatomical elements (Gaspary, 1950; González, 1947; Greslebin, 1931; Guarido et al., 2016; Scabuzzo et al., 2015), as well as modifications associated with the manufacture of human bone tools (Acosta et al., 2011a). Here, we take the opportunity to summarize the abovementioned aspects and present new evidence that contributes to understanding the variability and complexity of corpse manipulation by pre-Hispanic societies in the lower Paraná River basin.

1.1. Hunter-gatherer societies from the lower Paraná River basin. Archaeological background

The lower Paraná River basin belongs to the Paraná Delta and Islands ecoregion in Argentina (Burkart et al., 2000). This area was inhabited by hunter-gatherer societies from at least 2400 years BP (Loponte et al., 2012). These societies had low residential mobility with

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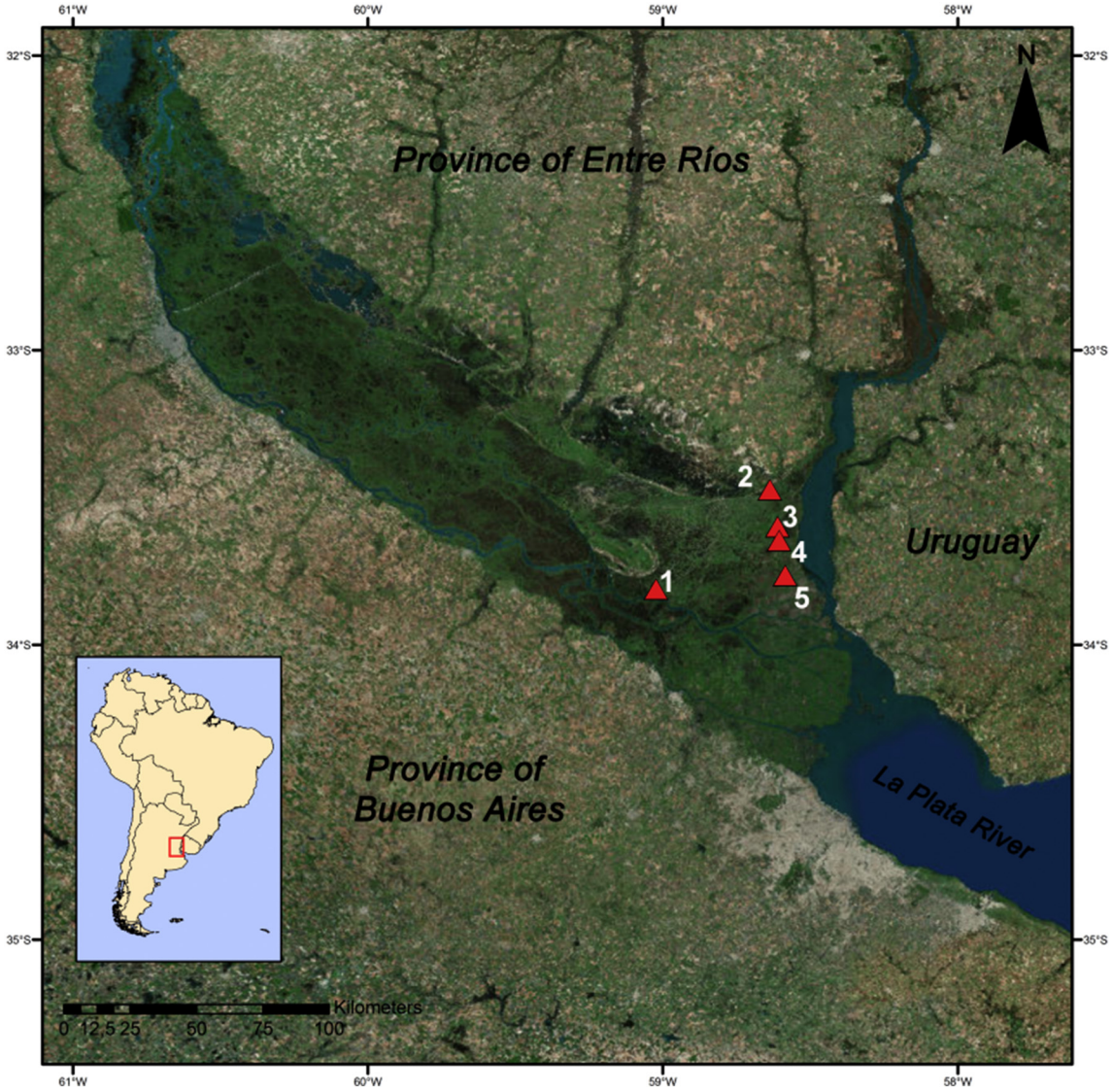

Fig. 1. Location of the archaeological sites under study. 1: Escuela 31; 2: Cerro Mayor; 3: Las Ánimas; 4: Cerro Lutz; 5: Túmulo 1 del Brazo Largo.

an economy based mainly on fishing (Characiformes and Siluriformes Orders) and on deer (*Blastocerus dichotomus* and *Ozotoceros bezoarticus*) and small game (*Myocastor coypus* and *Cavia aperea*) hunting. The agroforestry of local palms and the development of sporadic small gardens have also been postulated, in addition to mollusk and wild plant gathering (Acosta and Ríos Román, 2013; Loponte, 2008; Lothrop, 1932). The archaeological record shows extensive use of pottery for processing food and increasing the ability to extract nutrients through boiling (Loponte, 2008; Pérez et al., 2013). The ethnographic and archaeological record of these societies demonstrates a sophisticated range of tools, including bows and arrows, harpoons, spear throwers, *boleadoras*, traps and fishnets (Buc, 2012; Loponte, 2008; Sacur Silvestre et al., 2013). Another important characteristic of these societies was the diversity of their mortuary customs. Since the first archaeological investigations in this area, many researchers have highlighted the presence of primary burials in different positions and orientations, as well as different types of secondary interments (mortuary packages, accumulations of long bones, isolated craniums and other anatomical units) (Gaspary, 1950; Gatto, 1939; González, 1947; Greslebin, 1931; Lothrop, 1932; Mazza, 2010; Torres, 1911). Moreover, some researchers have found thermally altered human bones at the following archaeological sites: Túmulo de Lucuix (Greslebin, 1931), Cerro Grande de Isla Los Marinos (Gaspary, 1950), Cerro Grande del Paraná Pavón (González, 1947) and Los Tres Cerros 1 (Scabuzzo et al., 2015). This final piece of evidence is the only archeological background to have a possible anthropogenic postmortem modification of human bones. All of the abovementioned researchers have stressed the secondary mortuary treatment of burned remains and some have been able to estimate the age and sex of the individuals involved. They were adults who were either young or of an indeterminate age (Gaspary, 1950; Scabuzzo et al., 2015). In addition, the burned bones from Cerro Grande de Isla Los Marinos, Cerro Grande del Paraná Pavón and Los Tres Cerros 1 were painted with red ochre. The human occupation at Cerro Grande de Isla Los Marinos was dated from between 1275 and 1625 cal AD[1] (460 ± 50 and 660 ± 70 years ^{14}C BP [LP 2464, LP 2369; respectively]; Kozameh and Brunas, 2013) and the burned bones from Los Tres Cerros 1 from between 1072 and 1406 cal AD (775 ± 85 years ^{14}C BP [AA-93218]; Scabuzzo et al., 2015).

Although the abovementioned archaeological record is characteristic of the entire region, recent analyses have distinguished at least three archaeological units (from now on: AUs) based mainly on pottery style. The first AU belongs to archaeological sites with a predominance

[1] The samples were calibrated with Calib Rev. 7.0.4 (Stuiver and Reimer, 1993) with SHcal13 curve. Age-ranges are at a 95.4% probability (2 sigma); maximum p-value.

of plain pottery and a faunal assemblage dominated by fish and, secondarily, by mammals. Another associated trait is the T-shaped *tembetás*, a pierced-lip ornament made of aquatic bivalve mollusks. The second AU corresponds to archaeological sites with a high proportion of incised pottery with geometric patterns, with a higher consumption of mammals in relation to fish and, perhaps, *tembetás* or circular pierced-lip ornaments (cf. Loponte, 2008). The last AU is known as Goya-Malabrigo, stylistically characterized by pottery handles with zoomorphic figures, among other features (cf. Loponte and Acosta, 2016a). There were no chronological differences between the three AUs; on the contrary, they were found throughout the entire chronological range, and they share enough cultural similarities to be included under the single name of complex hunter-gatherer organizations (cf. Loponte et al., 2006).

2. Materials and methods

2.1. Materials

The sample comprises 1780 anatomical units from five archaeological sites; one of these sites belongs to the AU Goya-Malabrigo: Escuela 31 (n = 226); the rest correspond to the Plain Pottery cluster: Las Ánimas (n = 114), Cerro Mayor (n = 202), Cerro Lutz (n = 1231) and Túmulo 1 del Brazo Largo (n = 7). The latter is only included in this AU with a degree of doubt, as its original context is little known and there are only a few reported sampling results (Torres, 1911: 356). Moreover, the area where this site is located is one of the least archaeologically known in the region.

The incidence of taphonomic processes (biotic and abiotic) did not significantly affect the human remains, which contributed to the sample´s good state of preservation; a similar situation occurred with the faunal remains (Acosta, 2005; Loponte, 2008). Both assemblages present low degrees of weathering (between 0 and 1), low percentages of carnivore and rodent gnawing marks (0–2% of bone assemblage), root imprints, and a low to medium presence (0–50% of bone surface affected) of calcium carbonate and manganese dioxide.

2.1.1. Escuela 31

Located on the southern tip of Entre Ríos province, this site is in a sub-regional sector known as Floodplains, on the left bank of the Paraná Guazú River. The site was artificially elevated over a former hill (90 cm high). The sedimentary matrix consists of lots of sand-clay layers with a breccia-like microstructure, whose disposition and distribution suggest that they were added intentionally within a short period of time. Radiocarbon dating supports this hypothesis. The three dates obtained from the top, middle and base of the hill present statistically indistinguishable values at the 95% level (T-test = 0.637; $\chi^2 = 5.99$, $df = 2$): 247–517 cal AD (1712 ± 47 years ^{14}C BP [AA103649]); 229–475 cal years AD (1732 ± 50 years ^{14}C BP [AA103650]) and 220–415 cal AD (1764 ± 46 years ^{14}C BP [AA103651]), respectively. The excavated surface area was 38 m^2.

The material record consists of large numbers of pottery fragments, silicified limestone flakes and cores, and polished lithic tools. The faunal remains comprise medial and large mammal and fish species (Loponte et al., 2015).

With regard to human remains, a minimal of six individuals were recovered from primary, secondary and indeterminate burials (Mazza et al., 2015). The primary burials consisted of two adult individuals of both sexes (ESC31-E1: female, ESC31-E2: male; both 35–50 years of age). Individual ESC31-E1 was dated 131–381 cal AD (1807 ± 47 years ^{14}C BP [AA103644]). The secondary burial (ESC31-E3) was composed of a cranium and, mainly, long bones from the upper and lower limbs, arranged parallel to each other and piled up (the minimal anatomical unit percentages, %MAU, of the secondary burial can be seen in Fig. 2). This mortuary structure was composed of at least of two indeterminate adult individuals of both sexes (ESC31-E3a: male and ESC31-E3b: possible female). The indeterminate burials belonged to two individuals (ESC31-E4: indeterminate adult, possible male; ESC31-E5: a subadult of 32–34 weeks gestation), which were removed from the field by local people prior to the archaeologists' arrival.

2.1.2. Cerro Mayor

Located 60 km southwest from the Escuela 31 archaeological site, this site is in the southeast of Entre Ríos province, in the Floodplains sub-region, on a late Holocene coastal cordon. The sedimentary matrix is in multi-overlapping layers ranging from 1 to 10 cm thick composed of several different sedimentary aggregates or preparations. The samples recovered from the stratigraphic levels at a depth of 20–30 cm to 220–230 cm were chronologically located between 432 and 579 cal AD (1561 ± 45 [AA97469] and 1600 ± 33 years ^{14}C BP [AA97466]; Loponte et al., 2016). These radiocarbon dates together with the complex sedimentary matrix suggest that this archaeological site was also artificially elevated. The estimated elevation was approximately 6 m and the excavated surface area was 4 m^2 (Loponte et al., 2016).

The material record mainly consists of plain pottery fragments of open bowls and cooking pots, silicified limestone flakes and cores, and some quartzitic sandstone fragments (Loponte et al., 2016). Fish predominate in the faunal record, whereas deer and rodents (*Ozotoceros bezoarticus*, *Blastocerus dichotomus*, *Hydrochaeris hydrochaeris* and *Myocastor coypus*) are present in low frequencies. It is important to highlight the recovery of two *Canis familiaris* individuals, represented by two ulnas, one radius and one inferior molar. One of them was dated 390–633 cal AD (1594 ± 59 years ^{14}C BP [AA103658]; Loponte and Acosta, 2016b).

The mortuary record is represented by five individuals from one secondary burial and two indeterminate burials whose pattern does not allow us to accurately discern between the primary or secondary burial of the remains. The secondary burial was found at a depth of 230–240 cm and contains the remains of a single juvenile individual, possibly male (CM-E1: 12–14 years of age) (Fig. 2). His remains were painted with red ochre and they were in an unusual spatial organization. The cranium was at one end of the assemblage, along with the femora and other long bones, while the plain bones were located in the middle of the mortuary structure. This individual was associated with lots of shell beads and was dated at 258–568 cal AD (1665 ± 45 years ^{14}C BP [AA97468]; Loponte et al., 2016). At the opposite end of the cranium, we recovered some anatomical units belonging to an individual of 38–40 gestational weeks (CM-E2) that had been painted with red ochre. This individual could have belonged to the secondary burial, as previously described. The indeterminate burials belonged to at least two adult and one subadult individuals. The adult individuals (CM-E3 and CM-E4) were represented by only two pairs of articulated feet, hand bones and an accumulation of plain and irregular bones (scapula, vertebrae, patella and ribs). The subadult individual (CM-E5) was 3–4 years of age, although the bone arrangement did not allow any differentiation between a primary or secondary burial.

2.1.3. Cerro Lutz

Located on a hill in the southeast of Entre Ríos province, this site is in the Floodplains sub-region, on the left bank of the Martínez stream (Acosta et al., 2010a). The soil profile can be divided into three horizons, A, A/C and C. The A horizon contains most of the archaeological material, including human remains, and it ranges from 0 to 22–95 cm deep. Six radiocarbon dates locate the occupation between 1219 and 1131 cal AD (1100 ± 45 [AA103643]; 730 ± 70 years ^{14}C BP [LP-1711]; Acosta et al., 2010a). The excavated surface area was 15.85 m^2.

The material record mainly consists of plain pottery fragments of open and semi-open bowls; flakes made of silicified limestone, quartzitic sandstone, chert and quartz; bone tools (composed mainly of different types of points such as hollowed points, awls, bipoints and harpoons); and bone elements with saw marks on their perimeters (Buc and Sacur Silvestre, 2010). The faunal assemblage is primarily composed of

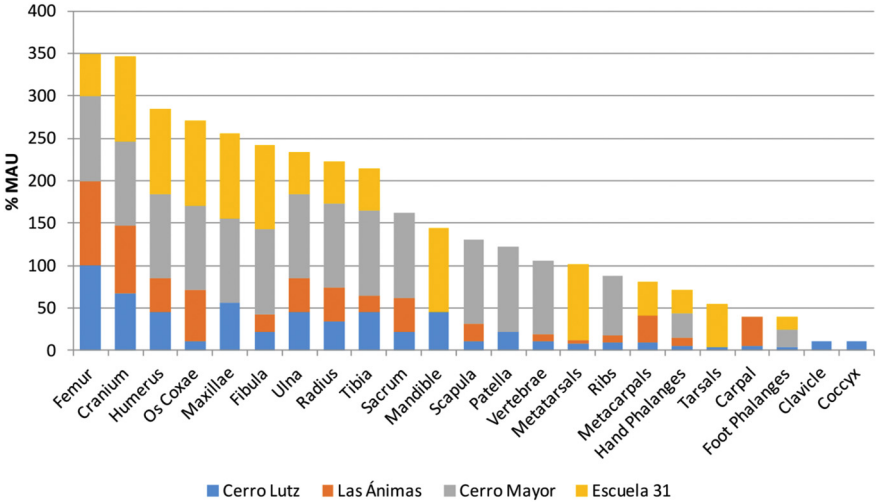

Fig. 2. Percentages of the minimal anatomical unit (%MAU) of the secondary burials for each archaeological site.

bivalve mollusks (*Diplodon* sp.), which makes this site a genuine shell-midden. 90% of the vertebrate faunal remains belong to fish (Siluriformes and Characiformes Orders), and, to a lesser extent, to deer and rodents (*Blastocerus dichotomus*, *O. bezoarticus*, *Cavia aperea*, *M. coypus*, *H. hydrochaeris*). In addition, there is a semi-complete *Canis lupus familiaris* skeleton (Acosta et al., 2011b).

A minimum of 39 individuals were recovered from 12 primary burials, 5 secondary burials and 5 indeterminate interments (Mazza, 2010; Mazza and Loponte, 2012). All of the burial types were composed of individuals of both sexes, adults and subadults. The primary burials were found in prone and supine positions, mainly with a west-east orientation. The differences in burial positions coincided with the sex of the individuals. The males were buried in a supine position, whereas the females were in a prone position (Mazza, 2010). The secondary burials contained the remains of multiple individuals and were classified into mortuary packages composed of long bones and a cranium, and of long bone accumulations and isolated craniums (Fig. 2). The indeterminate burials were the result of modern ploughing activity, and of the actions of roots and small fauna (Acosta et al., 2010a; Mazza, 2010). Further details about the mortuary practices and other biological analyses at Cerro Lutz have been already published (Mazza, 2010, 2016a; Mazza and Loponte, 2012).

2.1.4. Las Ánimas

This archaeological site is located on a hill in the southeast of Entre Ríos province, in the Floodplains sub-region, 5 km from Cerro Lutz (Loponte and Acosta, 2007). The soil profile has the same characteristics as at Cerro Lutz and the archaeological material and human remains are within a depth of 45–80 cm. The excavated surface area is 3.25 m^2. A radiocarbon date from one of the primary interments (LAN-1, see description below) locates the human occupation at 893–1022 cal AD (1121 ± 31 years ^{14}C BP [AA97460]; Acosta and Mazza, 2016).

Most of the recovered pottery fragments have no decoration (plain pottery). The lithic material is composed of silicified limestone flakes and the bone tools are composed of different types of points (e.g. awls, hollowed points). The faunal remains consist mainly of fish and secondarily of typical regional taxa (*B. dichotumus*, *O. bezoarticus*, *M. coypus* and *H. hydrochaeris*).

A minimum of 11 individuals were recovered from three primary, two secondary and one indeterminate burials (Acosta and Mazza, 2016; Guarido et al., 2016; Mazza et al., 2015). The first ones are represented by two subadult individuals (one possible male 4 ± 1 years of age, individual LAN-1, a possible female 2–3 years of age, individual LAN-4a) and an indeterminate adult (individual LAN-3) that is still in the field. There are two secondary burials, named LAN-2 and LAN-4b. LAN-2 contains the remains of one adult male individual (LAN-2.1) and a subadult 10-12 years old of unknown sex (LAN-2.2); both are represented by femurs and os coxae. The other secondary burial, LAN-4b, comprises the remains of two adult and three subadult individuals of different ages (11–12 years old, 2.5–3.5 years old and 1.5–2 years old; individuals LAN-4b.1, LAN-4b.2 and LAN-4b.3, respectively). The subadults are represented mainly by long bones. One of the adults from this secondary burial (LAN-4b.4) is possibly a male and is represented by several isolated anatomical units (sacrum, vertebrae, cranium, long bones, ribs and bones from the right hand) found among the subadult remains. The other adult individual (LAN-4b.5) consists of a left hand found in anatomical articulation. The hand bones of LAN-4b.4 and LAN-4b.5 showed differences in size, indicating the existence of two adult individuals. The minimal anatomical unit percentages (%MAU) of the secondary burials can be seen in Fig. 2. The indeterminate burial belonged to a subadult individual (LAN-6) whose remains were found together with individual LAN-3.

2.1.5. Túmulo 1 del Brazo Largo

This archaeological site was excavated at the beginning of the 20th century by Torres (1911). It is located in the southeast of Entre Ríos province, in a sub-regional sector known as Lower Delta, on a hill on the left bank of the Brazo Largo River. A human bone sample from Torres´ museum collection (Museo Nacional de Ciencias Naturales y Museo, La Plata) was recently dated at 1293–1406 cal AD (656 ± 42 years ^{14}C BP [AA-93219]; Bonomo et al., 2011).

According to the data published by Torres (1911), the pottery consists mainly of plain fragments, although there are some incised fragments with a geometric pattern. Bone tools such as awls, pin-like tools and different types of points were made mostly of deer bones, but a pin-like tool made out of a bird bone was also recorded (Buc and Coronel, 2013). The lithic assemblage comprises lots of hammerstones, a dimple stone and a pestle. The faunal remains consist of fish, mammals, rodents and large quantities of bivalve mollusks (possibly *Diplodon sp.*).

Torres recovered six adult individuals of both sexes (BL-117 to BL-122) that, according to his descriptions, could have been primary burials. Recent analyses reassessed the age and sex of these individuals (Mazza, 2015). Three are adult males, two older than 50 years of age (BL-117 and BL-122) and one between 35 and 50 years of age (BL-118). The remaining individuals are two females and one possible female. One is over 50 years old (BL-121) and the other is an indeterminate adult (BL-120). The last individual is a juvenile 12–20 years of age of indeterminate sex (BL-119).

2.2. Methods

The sex determination of the adult individuals was carried out mainly through examining the greater sciatic notch (Buikstra and Ubelaker, 1994) in combination with the Phenice (1969) technique for the pubis portion of the os coxae. These analyses were complemented with a qualitative scoring system for sexually dimorphic cranial features (mastoid process, nuchal crest, supraorbital margin, glabella and mental eminence; Buikstra and Ubelaker, 1994) and with a discriminant function for the mastoid process (Mazza, 2013). When these anatomical units were absent, the sex was estimated by using the discriminant functions for long bones (Mazza, 2016b), developed specifically for the studied area. The sex estimation for the subadult individuals followed Schutkowski's (1993) criteria.

The age estimation for the adult individuals was based on age-related changes on the auricular surface of the ilium (Lovejoy et al., 1985) and the pubic symphyseal surface (Brooks and Suchey, 1990) and, secondarily, using the cranial suture obliteration approach (Meindl and Lovejoy, 1985). In the case of the subadult individuals, the age estimation relied on dental development (Moorrees et al., 1963; Ubelaker, 1989), epiphyseal closure (Scheuer and Black, 2000) and long bone measurements (Fazekas and Kósa, 1978; Scheuer and Black, 2000).

Anthropogenic modifications were macroscopically registered under a strong, raking light with the help of a hand lens, stereo and metallurgical microscopes. In the last case, however, the depth of field did not allow us to take photomicrographs.

The thermally altered bones were analyzed following the criteria specified in experimental and forensic studies. There is some destruction of a bone´s organic and inorganic components when it is exposed to fire, leading to changes in color, fracturing, fragmentation and microstructural modifications to the cortical and trabecular tissue (Baby, 1954; Binford, 1963; Shipman et al., 1984; Stiner et al., 1995; Symes et al., 2008). In this work, we are focusing on color changes and macrofractures. A combination of the burning temperature, time and environment causes color changes to bone on a scale that gradually evolves from a translucent yellowish color to an opaque white (Stiner et al., 1995; Symes et al., 2008; among others). Translucent yellow is the color of unaltered bone, whereas black is associated with carbonization of the remains, and gray and white are related to calcination (Shipman et al., 1984; Stiner et al., 1995). Colorimetric changes to the bone surfaces were registered macroscopically based on the above-mentioned qualitative color scale (Mayne Correia, 1997; Mayne Correia and Beattie, 2002; Symes et al., 2008, 2014). The association of black-colored bones with burned bones has been criticized in recent years because certain agents (e.g. the deposition of manganese oxides) usually alters the color of the bone surfaces, leading to black staining (Fernández-Jalvo and Andrews, 2016; Shahack-Gross et al., 1997). Although manganese coating and burned bones have colors from yellowish to black (López-González et al., 2006), thermally altered bones also turn white in addition to certain typical fractures produced by fire (Shipman et al., 1984). Another difference is that although in some cases manganese appears as an overall black surface staining, its most typical pattern is patchy and dendritic (Fernández-Jalvo and Andrews, 2016). In the present study, we recorded the anatomical locations and changes in color to bone surfaces with other taphonomic modifications, such as the presence of fractures that were particularly related to the action of fire in forensic studies (i.e. curved transverse fractures and patina; Symes et al., 2008). In this sense, fractures caused by thermal alteration can usually be distinguished from other causative agents because of their morphology and distribution (Baby, 1954; Binford, 1963; Symes et al., 2008, 2014). In addition, we followed recent studies that established color changes and types of fractures in order to discern between human bodies who had been exposed to fire with and without soft tissue (Symes et al., 2008, 2014).

We distinguished two different types of tool marks; cut marks and saw marks. Cut marks are incisions that remain on the bone after the loading pressure with a sharp element (e.g. a lithic flake). We followed Binford's (1981) criteria to distinguish disarticulation from defleshing cut marks. Both are short and subparallel marks with a V-shaped in cross section, but disarticulation cut marks occur on bone´s articular surface or very near it; they are deep and transverse to a bone´s longitudinal axis. On the contrary, defleshing cut marks are located on long bone diaphyses; they are generally parallel or oblique to a bone´s longitudinal axis. Saw marks can be defined as a set of clear V-shaped cuts that are the result of sectioning the bone with a cutting edge (Acosta et al., 2014a, 2014b; David, 2008). In addition, we identified percussion marks which comprise negative flake scars that remain on bones after being hit with a hard element (e.g. hammerstones, hand axes). They have been identified as width marks with curved borders (Capaldo and Blumenschine, 1994).

Tool marks and postmortem fractures occurring in antiquity were distinguished from modern and recently-made marks by color differences on the cortical bone and fracture types (Johnson, 1985). Fracture surfaces in fresh or green bone have the same color as the outer cortical surface, whereas fracture surfaces in dry bones present a contrasting color. In addition, bone cracks when loading exceeds its tensile strength, leaving different types of fracture according to the state of the bone (Johnson, 1985). When a fresh bone breaks, shearing occurs along the collagen lines, producing spiral or helical fractures. On the contrary, fractures on dry bone are perpendicular, parallel or diagonal to the bone´s longitudinal axis.

Bone artefacts were defined when a bone modification was registered with the naked eye. Use-wear was described mainly following Legrand (2007; see Buc, 2012) and functional identification was made by comparing already published experimental patterns (Averbouh and Provenzano, 1998-1999; Buc, 2012; Camps-Fabrer, 1966; LeMoine, 1991).

Finally, we followed the criteria established by Binford (1981) and Fernández-Jalvo and Andrews (2011) in order to identify carnivore and human tooth marks. These marks can be classified as pits, punctures and scores (sensu Binford, 1981). Pits are related to the collapse of a cortical bone surface under tooth pressure, whereas punctures are characterized by perforations with depressed edges, and scores are cortical scratches left by tooth friction action. In addition, repeated gnawing on epiphyses and plain bones produces notches known as crenulated edges (Binford, 1981). Furthermore, there are other bone marks that are exclusively produced by humans; shallow linear marks and double-arched puncture marks, both identified in experimental studies and archaeological contexts (Fernández-Jalvo and Andrews, 2011).

3. Results

In Table 1 there is a summary of the anthropogenic bone modifications for each archaeological site. Detailed information about the modifications for each individual can be found in the Supplementary Material.

3.1. Thermal alterations

Bones with evidence of thermal alteration were found in 1.01% of the sample (Table 1). They came from secondary mortuary structures from Las Ánimas archaeological site: individuals LAN-2.1, LAN-4b.4 and LAN-4b.5 (Supplementary Material). As already mentioned in Section 2.1.4, LAN-2.1´s remains belong to a male adult; whereas individuals LAN-4b.4 and LAN-4b.5 are two adults of unknown sex.

LAN-2.1 is represented by fragments of right femur diaphysis, right ischium with acetabular fossa, and a fragment of the left acetabular fossa. As shown in Fig. 2-B, these anatomical units were found disarticulated. Some femoral fragments and the right acetabular fossa present evidence of thermal alteration. The femoral remains are brown, black and white in color, whereas the right acetabular fossa is

Table 1
Number and percentage of anatomical units with anthropogenic bone modifications for each archaeological site.

Archaeological site	n of anatomical units analyzed[a]	Burned bones		Cut marks		Saw marks		Fresh bone fractures		Carnivore marks		Other modifications	
		$n_{affected}$	%	$n_{affected}$	%	$n_{affected}$	%	$n_{affected}$	%	$n_{affected}$	%	$n_{affected}$	%
Escuela 31	226	0	0	1	0.44	0	0	1	0.44	1	0.44	1	0.44
Cerro Lutz	1231	0	0	1	0.08	2	0.16	0	0	0	0	0	0
Cerro Mayor	202	0	0	5	2.47	0	0	1	0.49	1	0.49	0	0
Las Ánimas	114	18	15.79	0	0	0	0	0	0	2	1.75	0	0
Túmulo 1 del Brazo Largo	7	0	0	0	0	0	0	0	0	0	0	1	14.28
Total	1780	18	1.01	7	0.39	2	0.11	2	0.11	4	0.22	2	0.11

[a] These numbers include primary and secondary burials.

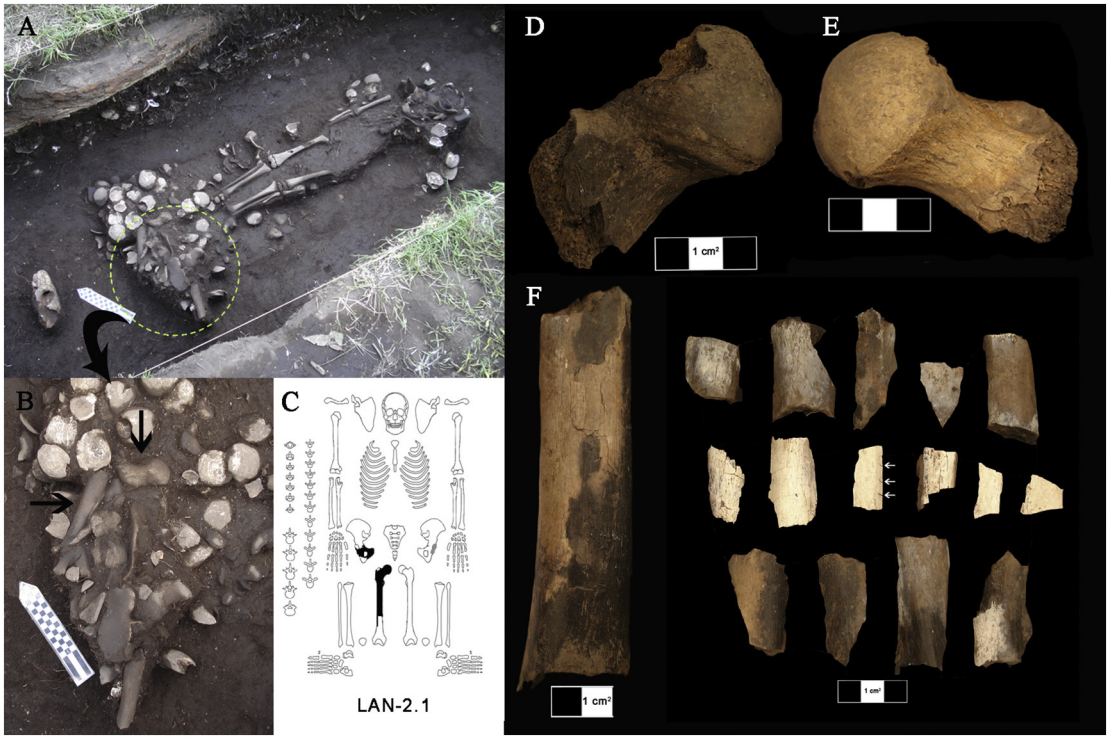

Fig. 3. Burned human bones from Las Ánimas archaeological site: individual LAN-2.1. A: Archaeological excavation unit with primary burial (LAN-1) in association with secondary burial (yellow dotted circle; LAN-2). B: Close-up view of the LAN-2 burial. The black arrows show LAN-2.1´s femoral fragments with evidence of thermal alteration. C: Anatomical representation of LAN-2.1. The burned bones are colored in black; the unburned bones are in gray. D: Anterior view of the charred right femoral head. E: Posterior view of the unburned right femoral head. F: Fragments of the right femoral diaphysis with different colors and fractures. The largest fragment from the left has patina fractures; the white arrows indicate curved transverse fractures. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

completely black. This coloration is consistent with charred and calcined bone. However, the femur is not completely burned. For example, the anterior portion of the femoral head presents evidence of burning (Fig. 3-D), while the contrary is the case for its dorsal part (Fig. 3-E). The same situation occurs in the diaphysis (Fig. 3-F), which also has several types of thermal fractures. They comprise patina (cracked surface) and curved transverse fractures (or muscle shrinkage lines; Symes et al., 2008:43), as well as longitudinal, helicoidal, transverse and step fractures (Fig. 3-F).

Individual LAN-4b.4 is represented by a sacrum, vertebrae, ribs, hand bones, cranium and long-bone fragments; all were found in a secondary burial among subadult skeletal remains (Fig. 4-A). LAN-4b.4´s bones show evidence of carbonization and calcination, ranging from brown to black in color and, to a lesser extent, white (Fig. 4-B). However, the right and left radius show differences in their coloration patterns. The left radius only has charred diaphysis, whereas the right radius has charred diaphysis and distal epiphysis (Fig. 4-B). Straight, step, longitudinal, irregular and patina fractures were recorded.

Finally, individual LAN-4b.5 is represented by an articulated left hand of an adult individual (Fig. 4-A dotted circle and Fig. 4-C). It shows thermal alterations in three proximal phalanges, two located in the distal articulation, and the third one in the diaphysis. They show brown to black coloration, all have step fractures.

3.2. Tool marks

Cut marks were detected on seven anatomical elements (0.39% of the sample; Table 1) from the Cerro Mayor, Escuela 31 and Cerro Lutz archaeological sites. The bones with cut marks came from secondary and indeterminate burials (Supplementary Material). The anatomical elements with cut marks belonged to at least three adult males, one subadult individual (possible male), and one adult individual whose sex could not be determined. The cut marks were generally located in the diaphyses, close to the epiphysis; they show V profiles, are arranged parallel to each other and have different lengths (Table 2, Figs. 5 and 6). Overall, these cut marks match those described by Binford (1981)

Fig. 4. Burned human bones from Las Ánimas archaeological site: individuals LAN-4b.4 and LAN-4b.5. A: Archaeological excavation unit with secondary burial (LAN-4b). B: LAN-4b.4´s thermally altered long bones. C: LAN-4b.5´s hand bones. The arrows point toward the burned bones. The left and right-hand skeletal drawings show anatomical representations of individuals LAN-4b.4 and LAN-4b.5, respectively; the burned bones are colored in black and the unburned bones are in gray.

and by Olsen and Shipman (1994) for disarticulation and defleshing practices.

At the Cerro Lutz archaeological site, left humeral and a right tibial diaphyseal fragments were found with saw marks on their perimeters (Acosta et al., 2011a). If we consider the cortical bone thickness and size of both bone fragments, it is possible to suggest that they belong to an adult individual. The humeral marks are located in the medial diaphysis, near the deltoid tuberosity. The tibial marks are located over the interosseous crest (Fig. 7). The saw marks would have been made when the bones were still fresh as they are very similar to those produced in experimental programs on fresh bones using lithic and shell edges (Buc et al., 2010).

3.3. Anthropogenic bone fractures

Anthropogenic bone fractures were found in 0.11% of a sample from two archaeological sites: Escuela 31 and Cerro Mayor (Table 1). At Escuela 31, together with the remains of individual ESC31-E4, an impact flake scar was identified on the anterior surface of a right distal femoral shaft (Fig. 8A), which also had cut marks near the scar (already analyzed in Section 3.2). The scar color and edges suggest that the fracture occurred when the bone was fresh (cf. Binford, 1981). The bone fragment size suggests that it belonged to an adult individual. The sex could not be determined.

At the Cerro Mayor archaeological site, a right humeral fragment had a helicoidal fracture along the diaphysis of the proximal end (Fig. 8B). This type of fracture suggests that the bone was broken while in a green state (Binford, 1981; Johnson, 1985). It is highly probable that this is an anthropogenic fracture, as it is highly unlikely that other agents (e.g. animal trampling) could have broken a bone of this size. The humerus belongs to an adult, possibly male individual (the humeral vertical head diameter was used to estimate the sex; Mazza, 2016b).

3.4. Bone artifacts

A bone tool made from an adult human radius was identified in the archaeological collection from Túmulo 1 del Brazo Largo, recovered by Torres (housed at the Museo Nacional de Ciencias Naturales y Museo, La Plata; Bonomo et al., 2009; Buc and Coronel, 2013). It can be defined as an awl based on its shape (Buc and Coronel, 2013; Fig. 9). The pointed apical end has a concave-convex cross section and it retains its proximal epiphysis at the base of the tool as a shaft (Type II sensu

Table 2
Description of cut marks.

Archaeological site	Individual	Burial type	Sex	Age (in years)	Anatomical unit	Anatomical location	n	Length (in mm)		Fig.
								Max.	Min.	
Cerro Mayor	CM-E3	Indeterminate	I	IA	Left talus	Medial malleolar surface	7	4.85	3.77	5-A
					Right talus	Lateral malleolar surface	1	2.9		5-A
	CM-E1	Secondary	PM	12–14	Left humerus	Distal anterior diaphysis	6	16.7	6.82	5-B
					Right tibia	Distal anterior diaphysis	7	13.79	11.2	5-B
	SR	Indeterminate	PM	IA	Right tibia	Proximal posterior diaphysis	12	10.55	3.88	6-A
Cerro Lutz	CL-E5a	Secondary	PM	IA	Left femur	Proximal anterior diaphysis	7	1.91	6.91	6-B
Escuela 31	ESC31-E4	Indeterminate	PM	IA	Right femur[a]	Distal anterior diaphysis	7	7.78	3.46	10-A

SR = superficial recollection; I = indeterminate; PM = possible male; M = male; IA = indeterminate adult.
[a] It also presents percussion marks.

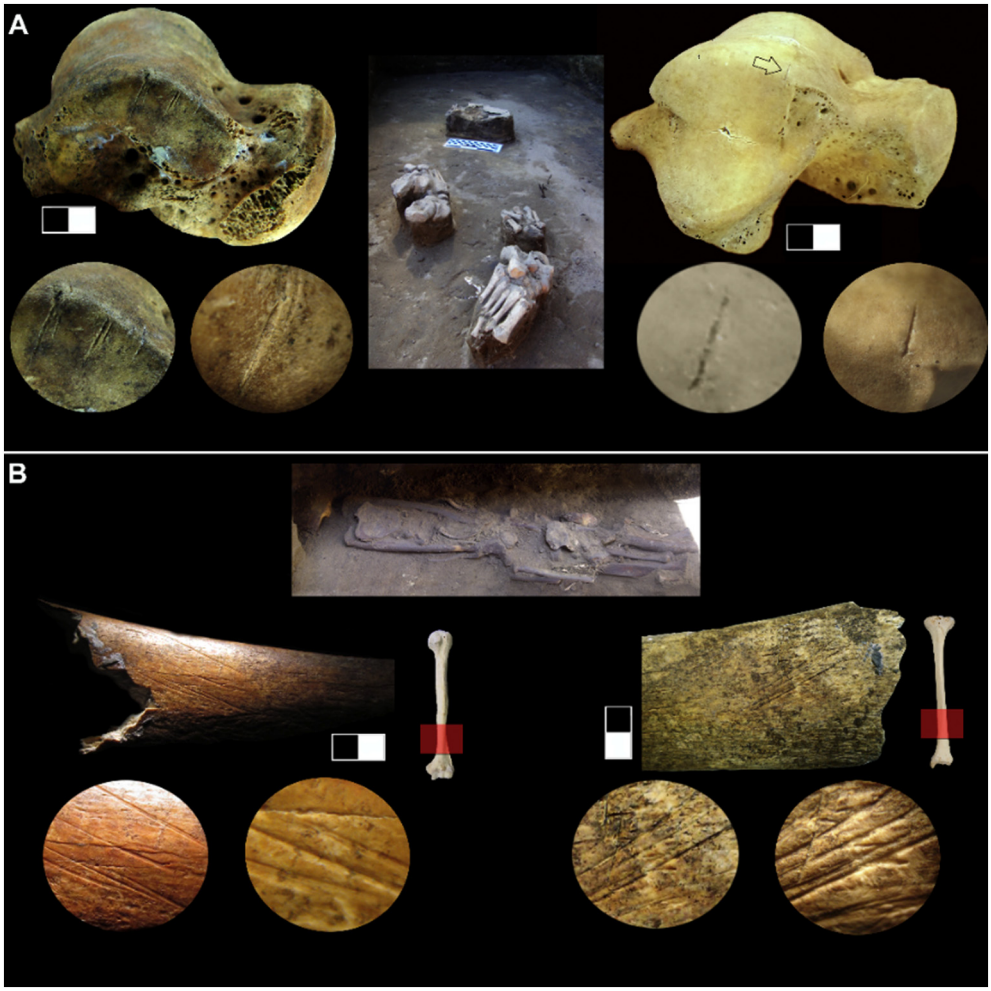

Fig. 5. Anatomical units with cut marks from the Cerro Mayor archaeological site. A: Burial context (middle image), left (left-hand image) and right (right-hand image) talus with cut marks (individual CM-E3). B: Burial context, humeral and tibial diaphyses with cut marks (individual CM-E1). The left-hand circular images were taken using a hand lens (5×); the right-hand circular images were taken with a stereomicroscope (40×). Scales 1 cm^2 divided into 0.5 mm^2.

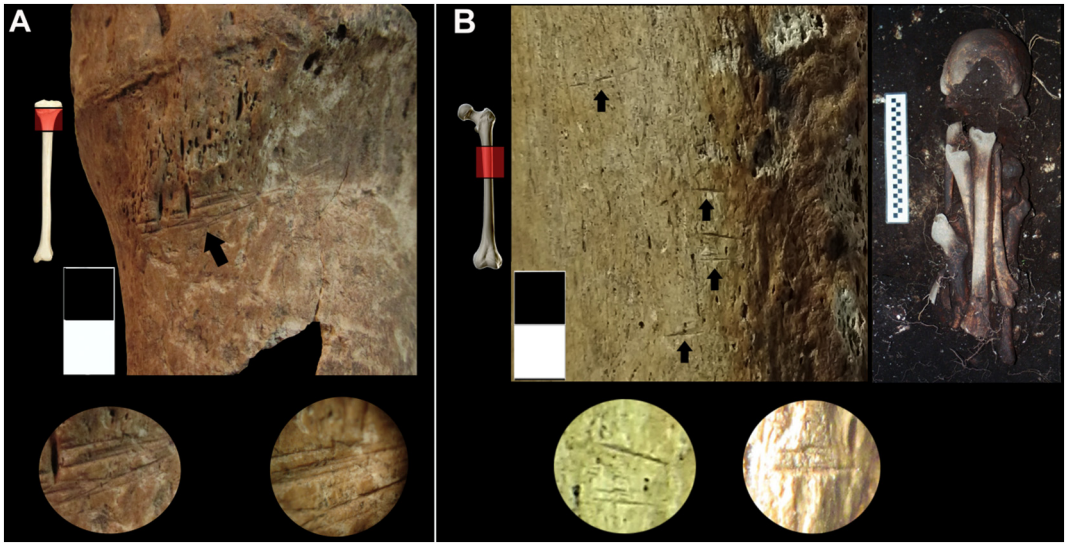

Fig. 6. A. Tibial cut marks from the Cerro Mayor archaeological site (surface recovery). B. Burial context and femoral cut marks from the Cerro Lutz archaeological site (individual CL-E5a). The left-hand circular images were taken using a hand lens (5×); the right-hand circular images were taken with a stereomicroscope (40×). Scales 1 cm^2 divided into 0.5 mm^2.

Fig. 7. Humeral and tibial fragments with saw marks on their perimeters from the Cerro Lutz archaeological site (taken and modified from Acosta et al., 2011a). The scale between the long bones is 1 cm^2, divided into 0.5 mm^2. The scale alongside the bone fragments is 0.5 cm^2, divided into 0.25 mm^2.

Camps-Fabrer, 1966:107). The proximal end is fused, indicating that this bone tool was made from an adult individual; and the head's antero-posterior diameter is 20 mm, which is possibly related to a female according to morphometric studies carried out on prehistoric local populations (Mazza, 2016b). This tool could not be analyzed for use-wear as it belongs to the museum collection.

At the Escuela 31 archaeological site, a modified left femur was recovered with the remains assigned to the individual ESC31-E4. The dorsal section of the diaphysis (at linea aspera) was completely abraded. A pattern consisting of long, parallel, coarse and longitudinal striations, related to a non-invasive polish, can be observed under high magnifications (i.e. recorded only at the high points of the microsurface; cf. Legrand, 2007; Fig. 10). This type of striation is known to occur after scraping the bone surface against a hard and coarse-grained material, such as the local quartzite. This pattern has been described as a result of bone regularization following the structure of the natural osseous surface (Averbouh and Provenzano, 1998-1999). Besides manufactured striations, no other evidence of anthropic use was recorded. However, the tool could have been used for a short period of time or for working a soft material, thus leaving no marks on the bone (LeMoine, 1991). Short and deep striations like "little wedges" were also recorded, although they could have been post-depositional marks because of their irregular shape (cf. Buc, 2012).

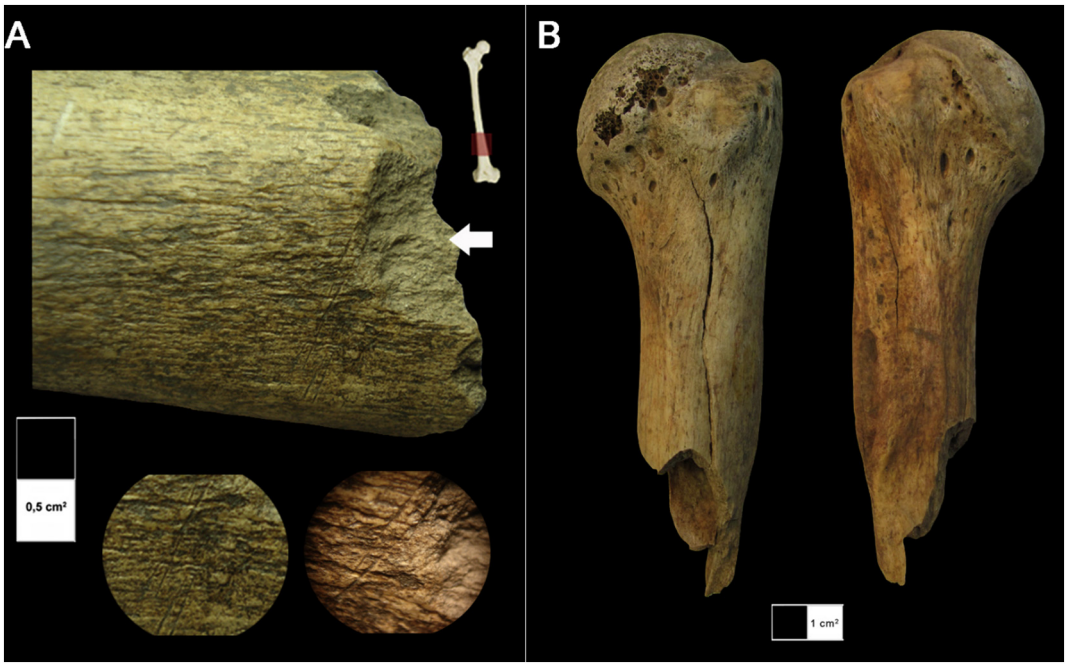

Fig. 8. A: Cut marks and impact flake scar on the anterior surface of a right distal femoral shaft (Escuela 31 archaeological site). The white arrow points toward the impact scar. The left-hand circular image is a magnification of the cut marks taken using a hand lens (5×); the right-hand circular image was taken with a stereomicroscope (40×). B: Anterior and posterior views of a right humerus with a helicoidal fracture on its proximal diaphysis (Cerro Mayor archaeological site).

Fig. 9. Awl made from a human radius from Túmulo 1 del Brazo Largo archaeological site. Luis María Torres Collection, Museo Nacional de Ciencias Naturales y Museo, La Plata: MLP-D25-CLMT N° (b) 4-5447 (taken and modified from Acosta et al., 2011a).

3.5. Carnivore and human tooth marks

No human tooth marks were observed in any of the analyzed anatomical units with anthropic modifications. Puncture marks made by carnivore teeth were found on 0.22% of the sample (Table 1). Specifically, they were registered on a fibula from Escuela 31 (individual ESC31-E3), on an ulna from Cerro Mayor (individual CM-E1) and on an ilium from Las Ánimas (individual LAN-4b.3) (Supplementary Material). The numbers of puncture marks were between one and two per anatomical unit. The low frequency of carnivore tooth marks is consistent with the patterns observed on faunal assemblages from the area under study (Acosta, 2005).

4. Discussion and conclusions

This work addresses some of the complex behaviors associated with corpse manipulation and treatment of the dead among hunter-gatherers from the lower Paraná River basin. The few works investigating post-mortem cultural modifications on human bones from the area under study only refer to thermal alteration (Gaspary, 1950; González, 1947; Greslebin, 1931; Scabuzzo et al., 2015). However, the presence of burned bones at the archaeological sites requires systematic analyses to discover whether they were burned intentionally or whether they were the consequence of post-depositional processes. González (1947: 34) cautioned about this last possibility and stated that the burned human bones from the Cerro Grande del Paraná Pavón archaeological site could have been the result of recent activities that affected the inhumation area, and were not necessarily related to funerary practices or cannibalism, as other authors have suggested (Gascué, 2009). In our sample, thermally altered bones were only registered in three adult individuals (LAN-2.1, LAN-4b.4 and LAN-4b.5) from Las Ánimas archaeological site. In the individual LAN-2.1, thermally altered bone fragments belonged to a right femur and an acetabular fossa. The registered bone color gradient along with the burned differences between the anterior and posterior surfaces of the femoral head had similarities with forensic situations where a body with soft tissue had been exposed to fire (Symes et al., 2008). In those cases, certain skeletal parts were more protected than others because of differences in muscle mass and due to the pugilistic posture that the body adopts when it comes into contact with fire. In this body position, the distal epiphyses, femoral greater trochanters and iliac crests are the first anatomical parts to lose soft tissue and, therefore, are the first ones to be burned. After that, burning continues with the diaphyses and anterior surfaces of the femoral heads. The last bones to burn are the posterior surfaces of the femoral heads, the sacrum and the ischia (Symes et al., 2008: 32–33). Femur fractures in individual LAN-2.1 also support our interpretation about the presence of soft tissue when the body was exposed to fire. Patina and curved transverse fractures are usually related to even superficial cortical bone shrinkage over the surface or to the incineration of soft protective tissue, especially when the bone receives uniform amounts of heat. It is important to mention that, although Gonçalves et al. (2011) suggested that curved transverse fractures also occur in dry bones, most experimental studies point to the contrary (e.g. Symes et al., 2008, 2014). The other types of identified fractures (longitudinal, helicoidal, transverse and step) are very common burn fractures, representing the shrinking of the bone matrix and its structural failure

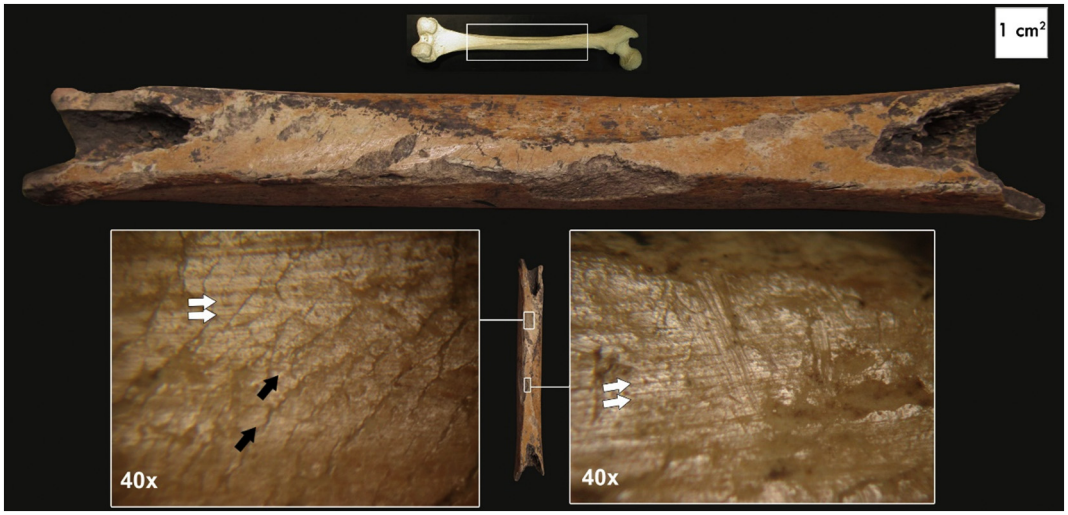

Fig. 10. Abraded femur at linea aspera from the Escuela 31 archaeological site. The white arrows point toward the transverse striations; the black arrows indicate possible post-depositional marks. The magnifications were taken with a stereomicroscope (40×).

after evaporation and protein denaturalization due to heating (Symes et al., 2008). Conversely, the bone color pattern in individual LAN-4b.4 cannot have been directly related to exposure to fire with soft tissue. As we recently mentioned, the epiphyses are the first to burn (Symes et al., 2008). LAN-4b.4 has a charred right radial distal epiphysis, whereas the left radius is only charred in the diaphysis, not in the epiphysis. Therefore, the color pattern on the right radius would match a burning situation with soft tissue, and the contrary for the left radius. Both bone elements seem to have belonged to the same individual due to similarities in bone morphology and measurements. Therefore, these color differences could have been related to the body position at the moment it came into contact with fire. In other words, if the left arm had not been exposed to fire, the left radius would probably have had a color pattern similar to burned corpses with no soft tissue.

In order to understand the burning pattern on the last individual (LAN 4B.5), we should explain some forensic patterns. Forensic studies have demonstrated that muscular shrinkage due to heat causes the hand to make a fist. Therefore, the dorsal surface of the metacarpals are the first to come into contact with fire, followed by the carpals and proximal phalanges, then the intermediate phalanges and, finally, the distal phalanges (Pope, 2007; Symes et al., 2008). However, thermally altered hand bones from Las Ánimas archaeological site present a different pattern; only the proximal and intermediate phalanges were burned. This suggests that the fire exposure would have occurred with no soft tissue. Nonetheless, there is a forensic case of a burned hand with soft tissue that did not make a fist, but the phalanges remained extended (Symes et al., 2008: 47). This was due to a previous radio-ulna fracture which had compromised the wrist flexor muscles. This meant the fracture prevented the hand from closing and, therefore, only the distal epiphyses of the proximal phalanges were burned. Although this pattern matches that of the hand of individual LAN-4B.5, no bones from the forearm was found; therefore, we cannot prove that this was the case in this skeleton. On the other hand, neither can the burned pattern on LAN 4B.5´s hand be related to an advanced stage of bodily decay. Experimental studies analyzing the patterns left on burned bones at different stages of decay indicated that if the muscles and tendons are present, the hand tends to make a fist anyway (Keough, 2013; Pope, 2007). In consequence, and in addition to the adopted pugilistic position of the body's extremities and the rapid consumption of the thin skin covering the wrist, the dorsal faces of the metacarpals and carpals are burned immediately (Pope, 2007). These were not the patterns observed on the burned hand at Las Ánimas archaeological site, as the dorsal surfaces of the metacarpals and carpals did not show any evidence of burning. However, pugilistic flexion and soft tissue protection are lost at advanced stages of decomposition (Keough et al., 2015), leading to a differential exposure of the parts of the skeleton. Therefore, besides the forearm fracture hypothesis, individual LAN-4b.5 could have been exposed to fire under an advanced stage of decomposition where tendons and muscles were absent. The presence of some amount of tissue is supported by the fact that the hand was found in an articulated position.

The abovementioned thermally altered bones do not have any tool marks; therefore, a possible marrow extraction hypothesis can be rejected. Furthermore, the observed bone patterns' colors are the result of combustion processes, which necessarily would have left carbon remains or burned sediments around or near the burials. However, this type of evidence was not found in the excavated area. Moreover, the thermally altered anatomical units were disarticulated and associated with other bones with no burnt evidence. Therefore, it can be proposed that the human bones were burned somewhere else and then transported to and disposed of in their final resting place. Overall, this evidence allows us to suggest that thermally altered bones are a regional variant of secondary burials. The possible factors or reasons that led to the burned human remains are completely unknown. However, it is remarkable that only the adult males showed evidence of incineration in Las Ánimas archaeological site. Similar situations were described in other sectors in the area under study, where thermally altered bones were also related to adult individuals (Gaspary, 1950; González, 1947; Scabuzzo et al., 2015). We lack information about the sex and numbers of individuals recovered with evidence of thermal alteration from Cerro Grande del Paraná Pavón (González, 1947) and Cerro Grande de Isla Los Marinos (Gaspary, 1950). At Los Tres Cerros 1, Scabuzzo et al. (2015) recovered two individuals, one male and another whose sex could not be determined. Sexual differentiation in mortuary practices has already been mentioned in other works. For example, at the Cerro Lutz archaeological site, the male individuals were buried in supine positions, whereas the females were in prone positions (Mazza, 2010). However, males were also found in prone positions and females in supine positions at other archaeological sites in the region (Acosta and Mazza, 2016; Scabuzzo et al., 2015). Furthermore, some adult male individuals were associated with carnivore remains, either canines (with or without perforations), as personal ornaments, or craniums (Acosta and Mazza, 2016). Another sex-related difference is the presence of copper sheets or green marks on adult male craniums (Mazza, 2015; Torres, 1911). Conversely, no special features were associated with females, with the exception of a woman found with a necklace made of 209 marine shell beads at the Arroyo Sarandí archaeological site (Lothrop, 1932). We do not yet understand the behavior that led to this differentiation between sexes and, specifically, between male individuals. In this context, it is possible that incineration was another behavior that was linked to male differentiation. However, the conservation of thermally altered bones could have made it difficult to estimate their sex, thus obscuring the presence of female individuals. The sex estimation of thermally altered bones is not always possible due to problems conserving diagnostically anatomical elements. In burned bone assemblages, most of the bones are very fragmented and broken into small pieces, thus preventing the conservation of the anatomical parts needed for estimating sex (os coxae, cranium or epiphyses). Therefore, although two male individuals with burned bones could be identified (one from the Tres Cerros 1 and one from Las Ánimas archaeological sites), we are far from discovering whether this funerary practice was directed toward male individuals. Moreover, the survival probability of subadult thermally altered bones is lower than that of adult individuals, due to differences in bone mineral density (Holck, 2001 in Lewis, 2006). Subadult bones are more fragile and, therefore, they turn to ash or small fragments when exposed to high temperatures for a long time, thus making it difficult to recover them in archaeological contexts (Holck, 2001 in Lewis, 2006; Warren and Maples, 1997). Although some authors have noted that in certain circumstances subadult bones could be recovered after combustion, the accumulative effects of other post-depositational agents should also be considered (Jæger and Johansen, 2013). Therefore, it is possible that the representation of only adult and male individuals is biased.

Another explanation for burned bones could be the intention of reducing body size due to funerary space saturation. Many post-1000 years ^{14}C BP archaeological sites are characterized by the presence of many individuals inside a small space. For example, at Cerro Lutz we recovered a minimum of 39 individuals from 19 m^2 and at Las Animas there were 11 individuals in 3,25 m^2. Therefore, high demographic density leads to space saturation, especially in places assigned to the dead; hence, the incineration of human remains could have been a solution. It is remarkable that burned remains mainly come from archaeological sites with radiocarbon dating post-1000 ^{14}C years BP. However, we still do not have enough evidence to support one explanation.

Another line of evidence discussed in this paper is cut marks. The cut marks described here may be related to funerary practices linked to body preparation. Secondary burials, represented through funerary packages, isolated bones and/or articulated anatomical segments, were a frequent funerary practice among the hunter-gatherers who inhabited the lower Paraná River basin (Gaspary, 1950; González, 1947; Greslebin, 1931; Lothrop, 1932; Mazza and Loponte, 2012; Scabuzzo

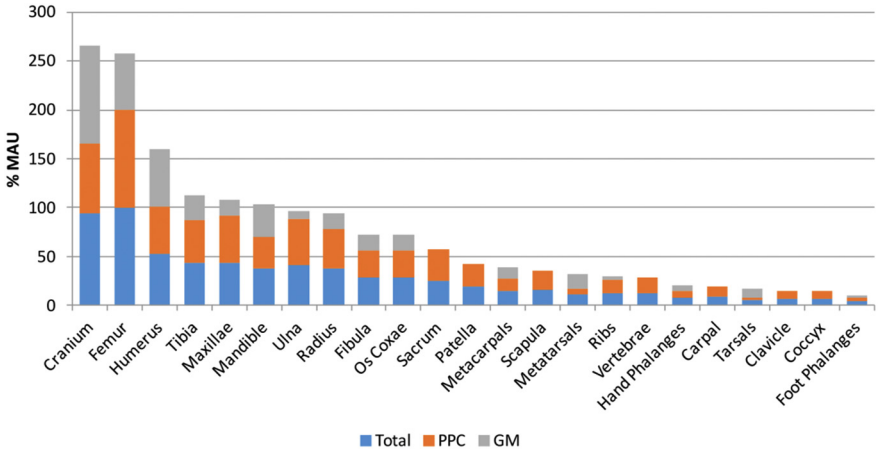

Fig. 11. Percentage of minimal anatomical units (% MAU) for the Plain Pottery (PPC) and Goya-Malabrigo clusters (GM) and total sample (Total = PPC + GM). The %MAU for the Goya-Malabrigo archaeological sites contains the human remains from Escuela 31 (analyzed in this work) as well as those published from Cerro Grande de Isla Los Marinos (Gaspary, 1950) and Cerro Grande del Paraná Pavón (González, 1947).

et al., 2015; Torres, 1911; among others). This mortuary behavior implied the selection of different bone elements (mainly long bones and craniums) from one or more individuals (Figs. 2 and 11). Cut marks are related to these mortuary practices; hence, it is possible that they were a byproduct of cleaning and disarticulating anatomical elements in order to prepare mortuary structures. In this sense, the length, frequency and distribution of the cut marks recorded on the humeral, femoral and tibial diaphyses suggest that they were the consequence of defleshing activities. Conversely, the ones recorded on the tali could have been related to disarticulating and segmenting the feet due to their anatomical proximity to the ligaments that attach the talus and calcaneus to the tibia and fibula.

It is possible that the presence and some properties of cut marks (for example, variations in length and frequency) were determined by the body´s state of decomposition at the moment of preparing the secondary burials (cf. Wallduck and Bello, 2016, 2018). Wallduck and Bello (2018) conducted a study of cut marks on different anatomical units of pigs, where they observed that the frequency of the cut marks depended mainly on the amount of soft tissue present on the bones at the moment the incisions were performed. There are two moments when cut marks are less visible: at the initial and final stages of bodily decay. At the first instance, the presence of liquids as a consequence of the decomposition of organic tissue makes the bone surface very slippery; hence, the cut marks are not produced. On the contrary, when the decay is more advanced, any organic tissue is easily cleaned without using a tool to cut or scrape it off. It is during the middle stages of bodily decomposition when the numbers of cut marks increases, as not much organic material is present on the bones. In the region under study, secondary burials are very frequent, but cut marks, when present, occur in extremely low frequencies (0.39%; Table 1). Therefore, and in relation to the investigations of Wallduck and Bello, we suggest that the bodies were buried for a period of time before the secondary burials were prepared (Acosta et al., 2011a). At this point, it is important to mention that the low frequency of carnivore tooth marks on human bones suggests rapid burial of the remains; which meant the decay process would have taken place mainly underground. This practice could have explained the presence of cut marks mainly in long bones near the epiphyses, as decomposition and skeletonization are not homogenous processes. The cranial and facial areas are the first to decompose, followed by the clavicles, sternum, cervical vertebrae, upper limbs, os coxae and lower limbs (Dirkmaat and Sienicki, 1995 in Roksandic, 2002), the joint connective tissue being the last to decompose (Stewart, 1979:69). This is the first analysis of cut marks related to burial practices among hunter-gatherers in the area under study, as those recorded in mid-Paraná contexts were not systematically described (Ceruti, 2003: 125). Future research will explore the multiple diagenetic pathways involved in bone degradation. The observation of histological changes will allow us to approach the conditions in which bones were integrated into archaeological deposits (Fernández-Jalvo et al., 2010; Jans et al., 2004; Turner-Walker and Jans, 2008). Bone modifications due to fungal or bacterial attack have been recorded with the objective of distinguishing between the deposition of human remains a short period of time after death from cases where the soft tissue was removed and the bones exposed prior to burial, such as cases of faunistic deposits (Jans et al., 2004; Turner-Walker and Jans, 2008). This information could be applied to exploring the dynamics involved in the formation of secondary burials. In addition, histological analyses could also be implemented for studying thermally altered bones in order to approach the maximum temperatures reached during combustion (Castillo et al., 2013; Hanson and Cain, 2007). This information is important for exploring the dynamics and energy involved in burning bodies.

The saw marks on the perimeters of bones from Cerro Lutz, the abraded femur from Escuela 31 and the awl from Túmulo 1 del Brazo Largo all indicate that human bones were occasionally used as raw materials. The low numbers of these kinds of finds suggest that they were a rare variant of human bone and corpse manipulation. However, the hunter-gatherer societies that inhabited the lower Paraná River basin had a complex bone technology and it cannot be discounted that some tools (e.g. stemmed points and bi-points; Buc, 2012), classified as Mammalia could have been made from human bones (Acosta et al., 2011a). Overall, there are few published works about human bones being used as raw materials among hunter-gatherer societies (e.g. Hester, 1969; McNeill, 2002, 2005; Verna and d'Errico, 2011). In the cases discussed in this paper, it is not easy to establish whether the choices of raw materials had symbolic connotations or whether they were strictly functional. The latter is a possibility in the context of a wide diversification of bone raw materials used for making tools. However, in the context of highly variable mortuary practices, which imply complex corpse manipulation (Acosta and Mazza, 2016; Loponte, 2008; Mazza and Loponte, 2012), we cannot discount that the use of human bones as raw materials would have been part of those mortuary practices. Furthermore, local bone technology mainly utilized local faunal remains, which were constantly available. Therefore, why use human bones? It is possible that this behavior was related to particular beliefs about and rituals for the dead. However, the context where they were found does not allow us to include and discuss them as grave goods because they were mixed with the rest of the archaeological materials (pottery fragments, faunal and human remains); an archaeological context that does not differ from other places with no human remains. A possible scenario is that human bone tools could have had an active social role, as a representation of a dead person (Hoskins, 1998; Jones, 2004; Sofaer, 2006). In this sense, there could have been a special relationship between people and human bone tools, whereby these objects could have had some kind of effect in their society by encoding or producing meaning (Hoskins, 1998; Jones, 2004; Sofaer,

2006, 2007). Hence, these kinds of objects could have been part of an ancestor cult, acting as active agents or representations of dead people. It has been argued that in these situations an object stands for a person; it materializes an identity (Jones, 2004; Sofaer, 2007). Unfortunately, we cannot go any further as the chronicles from the XVI century did not record this kind of practice, which would have allowed us to infer ways in which these objects might have interacted with the living.

Finally, the bones from Escuela 31 and Cerro Mayor showed evidence of having been fractured while still fresh, so they could have been related either to a secondary reduction of the body or to tool manufacturing practices. Although cannibalism has been associated with freshly-fractured bones (e.g. White, 1992), there is no certain evidence of this practice in the area under study. Human bone assemblages derived from cannibalistic practices present high frequencies of percussion marks and fractures, cut- and tooth marks, and evidence of thermal alteration (cf. Bello et al., 2016; Degusta, 1999; White, 1992). Moreover, in that context, the cut marks are located on the labile and permanent joints, whereas cut marks as a byproduct of mortuary practices are located on the permanent joints (Bello et al., 2016). In the lower Paraná River basin, no human bone assemblages have been identified with high percentages of the abovementioned variables and the cut marks were located on the permanent joints and diaphyses. In addition, the human bone assemblages differ from the zooarchaeological record. Although a comprehensive analysis of the faunal assemblages is beyond the scope of this paper, the bones of ungulates (*B. dichotomus* and *O. bezoarticus*), and of median and large mammals (between 25 and 120 kg), show clear evidence of consumption. They show high fragmentation indices, high numbers of fresh fractures and impact flake scares, as well as lots of cut marks related to disarticulating and defleshing different anatomical units (for more details about faunal processing and consumption in the area under study, see Acosta, 2005; Acosta et al., 2010b, 2014a, 2014b; Loponte, 2008; Mucciolo, 2010).

The burial evidence is not sufficient to state the existence of a mortuary pattern linked to a specific archaeological unit in the low Paraná River basin, besides that of the Guaraní, who were horticulturalist societies (cf. Loponte and Acosta, 2013). If we consider the archaeological sites included in this work, as well as ones from the northern and southern areas along the lower Paraná River, there are no properties in the mortuary record that can be differentiated regionally or culturally. In general terms, formal burial areas with primary and secondary inhumations, as well as articulated anatomical segments and isolated human bones, were found in many archaeological sites, independently of the archaeological units which they belong to (comparisons and examples of similarities in burial practices among different archaeological units can be found in Loponte and Acosta, 2016a; Mazza and Loponte, 2012). A similar situation occurs with the use of ochre for painting human bones and the presence of certain mortuary grave goods (e.g. faunal remains) (Acosta and Mazza, 2016; Caggiano, 1984; Caggiano et al., 1978; Ceruti, 2003; Gaspary, 1950; Gatto, 1939; González, 1947; Loponte and Acosta, 2016b; Scabuzzo et al., 2015). Burned human bones have been recorded at the Goya-Malabrigo archaeological sites (Cerro Grande de Isla Los Marinos, Cerro Grande del Paraná Pavón and Los Tres Cerros 1; Gaspary, 1950; González, 1947; Scabuzzo et al., 2015, respectively) and at Las Ánimas, which belongs to a different archaeological unit (see Section 2.1). A few bones with cut marks were recorded at Las Ánimas and Escuela 31, the latter with a Goya-Malabrigo context. Similarly, a few bones related to bone technology were recovered from Escuela 31, Cerro Lutz and Túmulo 1 del Brazo Largo, all with very different material assemblages (Table 1; Fig. 11; Supplementary Material).

To sum up, the mortuary record of the late Holocene hunter-gatherer societies from the lower Paraná River basin shows more similarities than differences between sub-regions, chronology and archaeological units. It is still difficult or premature to guess whether these similarities in funerary practices are part of a common belief system developed by social interaction, which implies a sharing of ideas and information between different local societies that could have coexisted in the area; or, whether they are a result of analogous evolutionary processes that developed in a shared environment. Local archaeological units share a cultural pool of practices that allow us to define them as complex hunter-gatherers (cf. Loponte et al., 2006) who adapted to a dynamic environment as is (and was) the Paraná River during the last 2500 years BP. This process implies, among other aspects, the development of social systems with density-dependent strategies, reduced residential mobility, spatial circumscription and behavior related to increasing the economic intensification of certain resources; in addition to the development of technological equipment (which allowed maximum prey capture and to increase their energetic return), the use of canoes, the development of local and extra-local exchange networks, and in some cases the artificial elevation of their residential camps where mortuary activities also took place.

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Declarations of interest

None

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2018.06.013.

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