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Evaluating Intensity in the Processing of Guanaco (Lama Guanicoe) at the Lower Basin of the Colorado River (Argentina): Fragmentation Levels and Fracture Patterns Analysis

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ABSTRACT This article explores the levels of fragmentation and fracture patterns in archaeofaunal assemblages from the lower basin of the Colorado River (Argentina) following Outram's methodology. Remains of ungulates (guanaco) have suffered, in these assemblages, a high degree of fragmentation probably caused during the processing of the carcasses. The presence of helical debris and shaft fragments indicates that fragmentation would respond to processing tasks for the consumption of marrow and possibly bone grease. The results of the application of this methodology that were obtained from the analysis of three late Holocene sites (La Primavera, Loma Ruiz 1 and El Tigre) are presented. These results provide new evidence not only for patterns of marrow and bone grease consumption but also for dealing with the subsistence model proposed for the study area. In this sense, the intensification processes already proposed during the final late Holocene (1000–250 BP) are discussed. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: lower basin of the Colorado River; late Holocene; fragmentation; bone fracturing index; intensification; guanaco

Introduction

Fat (both marrow and bone grease) is a critical nutrient for subsistence economies, mainly for hunter–gatherer societies that base their diet on proteins of animal origin and in which the consumption of carbohydrates is either minimal or nonexistent. In this sense, several researchers have pointed out that there is a limit in the amount of energy that can be provided by proteins and that diets that are too high in proteins can lead to nutritional deficiencies (Speth and Spielmann, 1983; Outram and Mulville, 2002; Sutton *et al.*, 2010). Therefore, eating other sources of calorific energy such as fat is important to keep an adequate nutritional balance. Fat not only possesses a larger calorific value than proteins and carbohydrates (9 versus 4 kcal/g) but also provides nutrients such as vitamins (A, D, E and K) and minerals like iron, phosphorus, calcium and magnesium (Outram, 2001; Outram and Mulville, 2002; Church and Lyman, 2003; Sutton *et al.*, 2010).

Moreover, from an ecological perspective, several authors indicate that the consumption of these nutrients may relate to an intensification of resource exploitation. In this respect, fat and marrow consumption would be a part of process in that skeletal parties are used more intensively to maximise the nutritional content of carcasses. These activities would generate highly fragmented assemblages (Butler and Campbell, 2004; Burger *et al.* 2005; Janetski 1997; Nagaoka 2005; Prendergast *et al.* 2009; see discussion in Stoessel 2011).

The research conducted in several areas of the Pampas and Patagonia regions (Argentina) have focussed on the leading role that ungulates played in the diet of Late Holocene hunter–gatherer societies (Miotti and Salemme 1999; Martínez and Gutiérrez, 2004; De Nigris and Mengoni Goñalons, 2005). Among the ungulates, guanaco is the dominant species in the faunal

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assemblages of this period. These are one of the largest wild ungulates of southern South America, and the weight average of adult individual is between 88 and 120 kg (Raedeke, 1978; Larrieu *et al.*, 1982). Ungulates have lean meat and small amounts of fat, and therefore the communities under study must have used different strategies to obtain it. One of the main sources that yield this product is the skeleton. The mandible and most of the appendicular elements contain marrow fat, whereas the epiphyses and the spongy, cancellous bone from the axial skeleton are rich in bone grease (Outram, 2001). Because of the different places where these nutrients are found, diverse techniques are necessary for their extraction. The bones need to be fractured to obtain the marrow, a fact that causes the long bone diaphyses and the mandible fragmentation. The exploitation of bone grease requires the boiling of the specimens. In this case, bones need to be reduced to very small fragments to facilitate their recuperation (Lupo and Schmitt, 1997; Mateos, 2002; Munro and Bar-Oz, 2005). From an archaeological point of view, taking the modifications that these techniques have originated, the consumption of these nutrients can be studied by analysing certain characteristics of the bone assemblages. In general, archaeofaunal analysis has emphasised bones exploitation to obtain fat and marrow using the presence of fresh state fractures as a criterion. In this sense, the presence of spiral fractures has been considered as an indicative feature that bones have been intentionally broken for bone marrow consumption (Outram, 2001, 2002). Nevertheless, to evaluate the intensity of exploitation, other variables need to be considered, such as levels of fragmentation that assemblages present, which requires the analysis of all remains. However, highly fragmented assemblages have a large quantity of remains that cannot be assigned to specifics skeletal parts and species and are considered as indeterminate fragments and excluded from this analysis (Outram, 2001). Nevertheless, the analysis of these remains can provide information to understand different aspects related to the exploitation. Outram (2001) suggested that to study fat and marrow, exploitation is not essential to know the element or taxon. It is important to study the levels of fragmentation and its cause to understand the exploitation of nutrients, how intense was the same and if the bones have been exploited to obtain marrow and/or fat. Thus, the fragments may be determined in relation to its size, weight and bone types (e.g. spongy or cortical). In the case of larger fragments, it is important differentiate whether the fragments corresponding to axial or appendicular skeleton can be possible (Outram, 2001).

Several authors have developed different indices to assess the fragmentation degree that assemblages present. Among them, Lyman (1994) developed a method on the basis of the number of identifiable specimen (NISP)/minimum number of element (MNE) rates, in which the identified specimen number is compared with the minimum number of items represented. This author stated that this method is useful to evaluate the degree of nutrients exploitation such as bone marrow and fat. It is also considered that it is possible to plot NISP/MNE rates of bones that contain bone marrow against a marrow utility index and thus predict which skeletal parts would be more fractured (Lyman 1994). Morlan (1994) developed a method on the basis of the 'completeness percentage', which requires prior determination of identifiable bones portions. The completeness percentage of each element is calculated once these parts are counted. The total number of preserved portion is the sum of MNE values for each element, and then these values are divided by the NISP, yielding an average number of portions per specimen. This average is divided by the number of defined portions to obtain the completeness percentage (Morlan, 1994). The use of these indices provides information about the fragmentation of the assemblages. However, these have been developed to assess the degree of fragmentation only of identifiable remains, leaving out the analysis of indeterminate fragments (Outram, 2001).

Outram (2001) used a more detailed method to assess the degree of fragmentation, which includes the analysis of the indeterminate remains. In these sense, this author has developed a methodology used to analyse the fracture patterns and fragmentation levels of bone remains. The use of this methodology is adequate to evaluate the consumption of marrow and bone grease in highly fragmented assemblages, such as the archaeofaunal assemblages at the lower basin of the Colorado River (see next paragraph), because it involves a detailed analysis of all bone remains. In the Materials and Methods section, the particularities of this methodology are explained.

The archaeofaunal assemblages found in several sites of the lower basin of the Colorado River (Argentina) present a high degree of fragmentation, and it has been considered that this would be due to the processing of ungulates (guanaco) carcasses, and in some cases it would correspond to an intensive exploitation aimed at the consumption of nutrients such as bone marrow. However, to determine how intensive the former has been, it is necessary to deepen on the origin of the high degree of fragmentation that these archaeofaunal assemblages present, by integrating the different types of information related to the levels of fragmentation,

the type of fragmented bone (e.g. spongy, cortical), the fracture patterns, and so on. In this sense, this article presents the results obtained from the analysis of the archaeofaunal assemblages of the site's La Primavera, Loma Ruiz 1 and El Tigre (Figure 1), by using the methodology proposed by Outram (2001, 2002). These studies will provide a useful line of evidence to evaluate the causes of fragmentation and its intensity and to determine if it corresponds to the consumption of marrow and/or grease because these are essential aspects to evaluate the subsistence model proposed for the area under study and the change that has been proposed towards the final part of the Late Holocene (see next section), considering that the sites correspond to different temporal moments (La Primavera and Loma Ruiz 1: Initial Late Holocene, 3000–1000 BP; El Tigre: Final Late Holocene, 1000–250 BP).

General characteristics of the study area and subsistence model

The lower basin of the Colorado River (Buenos Aires Province, Argentina) is located in a Pampean–Patagonian transition zone that is linked to the Atlantic shore and presents particularities regarding the resource's availability because of its ecotonal situation, from a zoo, phytographic and ichthyographic point of view (see Stoessel, 2007, 2010; Martínez, 2008–2009). Systematic research on the different lines of analysis that has been undertaken over the current decade has produced information that allows the characterisation of different aspects of the hunter–gatherer groups that inhabited the area from 3000 to 250 BP (see Martínez, 2008–2009, and the articles quoted there).

With regard to subsistence, a model was posed on the basis of the analysis performed on the archaeofaunal assemblages that are going to be presented in this article together with the evidence obtained from other sites located in the same area such as La Petrona (ca. 500–250 BP; Martínez and Figuerero Torres, 2000) and Don Aldo 1(ca. 800 BP; Prates *et al.*, 2006) as well as the evidence yielded from grinding materials and isotopic analysis of human bone remains (Stoessel, 2006, 2007; Martínez *et al.*, 2009a). The model proposes that during the Late Holocene, diet was mainly based on guanaco exploitation, complemented with the consumption of Pampas deer (*Ozotoceros bezoarticus*) and ñandú (*Rhea americana*) and the contribution of vegetable resources (Stoessel, 2006). This general

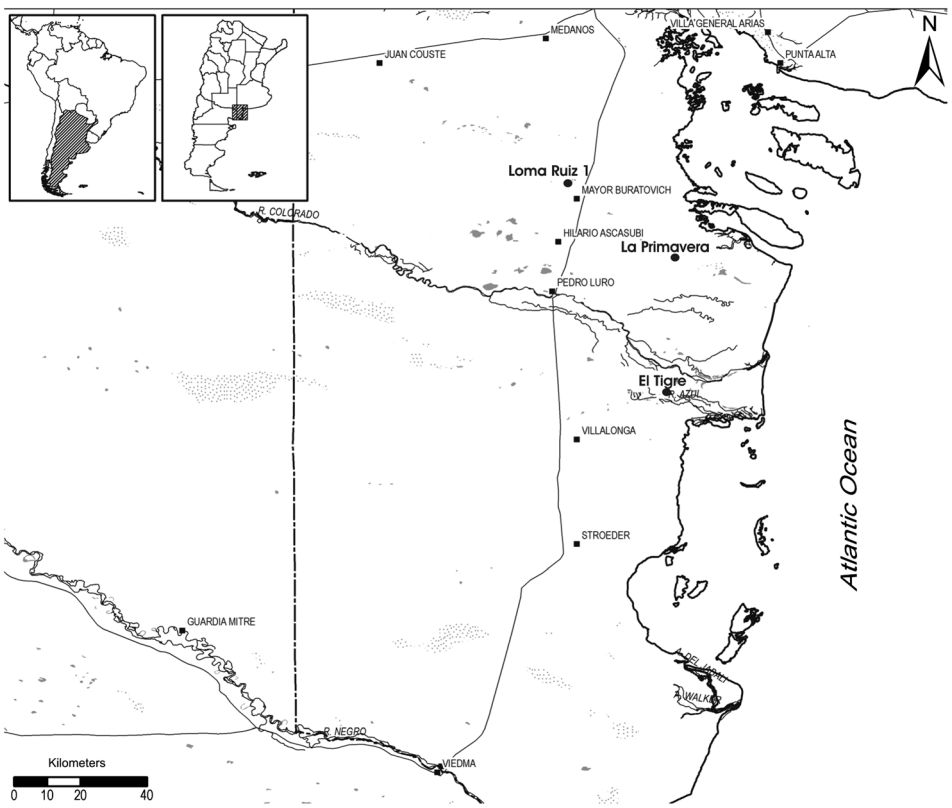

Figure 1. Map of the study area with the location of the analysed sites. (Taken and modified from Stoessel, 2010.)

model proposes changes towards the end of the Late Holocene (ca. 1000–250 BP), linked to the inclusion in the diet of a wider variety of smaller species such as birds, rodents and fish. Likewise, the characteristics that some faunistic assemblages from this period present (e.g. high degree of fragmentation, high frequency of helicoidal debris and shaft fragments), such as the El Tigre case, would indicate the existence of an intensification process reflected in the exploitation of certain resources (e.g. guanaco; Stoessel, 2006). This process would have occurred within the framework of societies that experienced changes in their settlement system (longer stays) in the given time span as well as the reoccupation of certain places of the landscape, larger population and spatial circumscription, mobility reduction, social interaction among groups, and so on (Barrientos and Pérez, 2004; Berón, 2004; Gómez Otero, 2006; Martínez, 2008–2009).

Materials and methods

Outram (2001) posed a series of archaeological expectations that would correspond to different situations linked to marrow and bone grease exploitation, each one related to a distinctive fracture and fragmentation pattern. In the first place, if none of these two nutrients has been exploited, the bones will be therefore largely deposited, complete or with limited damage as by-products of the butchering and initial processing of the prey. If only the bone marrow has been exploited, one would expect the previously mentioned damage; however, evidence of deliberate long bone shaft fractures (e.g. shaft fragments and splinters bearing evidence of dynamic impact when the bone was in a fresh state) and articulations will be also deposited whole, as will most axial elements. In the case of complete processing of bones for marrow and grease, a very different pattern will emerge. On the one hand, bone diaphyses will have suffered a dynamic fracture while fresh, and there will be many resultant shaft splinters. Furthermore, on the other hand, cancellous bone tissue, both axial and appendicular, will have been comminuted, and minute shaft splinters would be present (Outram, 2001).

It is also possible that, taking into account that these nutrients are differentially distributed in the skeleton, a selection of the bones to be exploited can exist. Hence, the processing will be incomplete. Finally, there may be lower intensity grease production rather than selection of particular elements. In such a case, the general pattern would be similar to that of complete processing, but several elements would survive undamaged (Outram, 2001). To evaluate these archaeological expectations, Outram (2001) developed a methodology that analyses a level of fragmentation on the one hand and the fracture patterns on the other. In the first case, the fragments are separated into classes according to size and within these, discriminated according to the type of bone (e.g. diaphyses, axial cancellous fragments and appendicular cancellous fragments). The different classes are quantified considering both the number of fragments and their mass. Complete bones and epiphyses (skeletal part fragments) are considered discrete classes. Outram (2001) developed a fracture freshness index (FFI) to analyse the fracture patterns in diaphyses that take three criteria into account defined by Johnson (1985) and used by Villa and Mahieu (1991): fracture angle, fracture outline and fracture edge texture. For each criterion, 0 denotes a fresh-fractured bone, 1 denotes a specimen with mixed features and 2 denotes a mainly unfresh specimen. To calculate the index that corresponds to each fragment, the scores for each of the three criteria were added to give a total range of 0 to 6, where 0 indicates that the specimen is fully consistent with fresh fracture and 6 indicates that it lacks all the traits related to it. The specimen whose index is lower than 3 corresponds to fresh fracturing, whereas those that have higher index numbers indicate dry fracturing. Finally, to deal with the fracture's origin, an average is obtained from the three criterion values that are added, and the assemblage fresh fracture index is obtained. This methodology was used for the analysis of approximately 750 bone remains from La Primavera site, approximately 9000 from Loma Ruiz 1 and approximately 41 000 remains from El Tigre site. In the fracture pattern analysis, in every case, shaft fragments larger than 30 mm were considered because of the high degree of fragmentation that the assemblages present (for an example of use of this methodology in Southern Patagonia, see Bourlot, 2009). The shaft fragments larger than 30 mm were selected because it was considered appropriate to analyse the specimens in which all attributes needed to implement the methodology (angle, texture and shape) could be observed. To analyse fragmentation levels, the different size categories proposed by Outram (2001) were considered. In this article, the smallest size category corresponds to 10–19 mm. In the analysed assemblages, smaller fragments that can be included in another category (0–9 mm) have not been recovered. This may be related to the diameter of the mesh sieve (less than 2 mm). However, considering this diameter if such specimens have been present should have been recovered. Then, the most probably is that they were not present in the assemblages, and consequently this category has not been considered.

However, to infer about subsistence, it is necessary to evaluate the taphonomic history of the assemblages to determine in what way the different processes may have conditioned their integrity and representability. In this sense, the taphonomic analysis of the faunal remains from Loma Ruiz 1 and El Tigre sites was conducted in previous studies (Stoessel, 2006, 2007) to evaluate the effects of different agents and/or processes that may have acted and modified the bone specimens surface and their spatial relationships on a contextual level. This article integrates these results with those obtained from the analysis performed at La Primavera site. The taphonomic effects that were considered were weathering (Behrensmeyer, 1978; Lyman and Fox, 1989), rodent's action (Binford, 1981; Bocek, 1986; Fisher, 1995; Falk and Semken, 1998), carnivore activity (Binford, 1981; Behrensmeyer, 1990; Thompson and Lee-Gorishti, 2007), trampling (Villa and Courtin, 1983; Olsen and Shipman, 1988; Lyman, 1994; Blasco *et al.*, 2008) and root's action (Behrensmeyer, 1978; Montalvo, 2002). At the same time, the %MAU frequencies of guanaco were correlated with the bone's mineral density to establish whether this variable has conditioned the skeletal parts representation. The values used were obtained by Elkin (1995) for camelids. This information will be taken into account for the discussion and interpretation of the data obtained from this research work.

Archaeological sites characteristics and archaeofaunistic assemblages analysis

La Primavera site

La Primavera Site is 5 km away from the left-hand margin of the Colorado River and 20 km away from its mouth (Figure 1). This site was detected in 1997 when infrastructure works related to construction of a canal exposed human bones associated with lithic and faunal materials. The first field work included the recovery of these archaeological remains. In 2000, systematic studies began on this site. Human remains from two burials have been found, as well as lithic, malacological and bone remains recovered from surface gatherings by five transects that were 2 m wide and 360 m long and a surface gathering conducted on the verge of the irrigation ditch (see Figure 2 of Bayón *et al.*, 2004). As regards the faunal remains recovered from transects 1, 3 and 5 analysed in previous studies, the results indicated that guanaco was the most highly represented species, followed by Pampas deer (*O. bezoarticus*) and ñandú (*R. americana*). It was also determined that guanaco was the only species in the assemblage that presented clear evidence of exploitation (e.g. cut marks, helicoidal fracture debris). However, it was proposed that the other two species mention would have been part of the diet too, for the contextual evidence (see discussion by Bayón *et al.*, 2004). Nevertheless, and as part of this research, the exploitation of all the material recovered from these transects has been confirmed by its analysis (e.g. anthropic fractures on long bones). On evaluating the different lines of evidence, it was established that the site would functionally correspond to a base camp of multiple activities, occupied during the initial Late Holocene (3000–2800 BP), in which inhumations took place (Bayón, *et al.*, 2004; Martínez, 2008–2009). With regard to the chronology, a radiocarbon dating (AMS) in individual 2 provided an age of 2800 ± 60 BP. Subsequently, two new samples of human remains were dated. These samples were dated between 2728 ± 48 and 2882 ± 49 BP. Part of the new analysis carried out on this site was dating two bones of

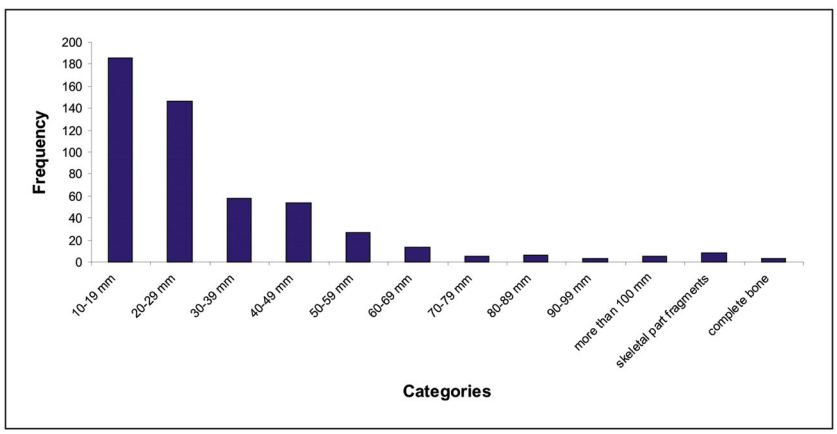

Figure 2. Bone fragments frequency sorted into size categories at La Primavera site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

guanaco (helicoidal debris), which provided ages of 2805 ± 50 and 2839 ± 50 BP. The dates obtained show a synchrony between inhumation practices and activities of prey consumption.

The analysis was performed on the faunal assemblages obtained from the five transects and the surface gathering from the verge of the channel (n = approximately 750).

Taphonomic analysis

The taphonomic analysis showed that this assemblage has been affected by different agents and processes. Among them, the roots action (~60%), abrasion (~70%) and weathering (~12%) were the main alterations observed in skeletal remains. The abrasion and weathering could be consequence to exposure of the remains. However, most specimens that showed evidence of weathering were in stage 1, indicating that the remains did not stay a long time on the surface. Also, the roots' action affected a high percentage of bones, indicating that this remained a long time in stratigraphy. In addition, manganese oxide stains (impressions, 4.56%) and rodent marks (6%) were detected in the bones. Therefore, this faunal assemblage has been buried, and then human activities associated with the infrastructure works reexposed the materials. The correlation between %MAU frequencies of guanaco and the bone mineral density were not significant. The correlation coefficient (Spearman's $rs = -0.2369$) is very low and is associated with a probability of the hypothesis of no relationship more than 0.05 ($p = 0.1641$). Therefore, this variable would not have influenced the skeletal parts representation. With respect to the correlation with meat and marrow indices, the Spearman correlation coefficient obtained is low (Spearman's $rs = 0.2068$) and is associated with a probability of $p = 0.2727$. This would indicate that there was no selectivity in favour of the parts that yield a higher economic profit.

Results

To evaluate the fragmentation level of the faunal assemblage, the bones were classified into size categories (10–19, 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, 80–89 and 90–99 mm; more than 100 mm; skeletal parts, fragment-complete, epiphysis and complete bones) and quantified by the number of elements and mass. There is a higher frequency of the categories 10–19 mm (36.18%; $n = 186$), 20–29 mm (28.40%; $n = 146$), 30–39 mm (11.28%; $n = 58$) and 40–49 mm (10.50%; $n = 54$) (Figure 2). This would indicate that fragmentation was important in this set.

When the fragments are quantified taking their mass into account, there is a predominance of the smaller sizes (Figure 3). Notwithstanding, in this case, the categories of larger size such as more than 100 mm and skeletal part fragments are well represented. Figure 4 shows the distribution of the bone elements in each category taking the percentage in which each bone is represented into account. Diaphyses amply dominate every category, except for those of skeletal part fragments and complete bones that are represented by the appendicular skeleton. The axial skeleton is present in almost every category although in a variable way, whereas the appendicular skeleton is only represented with different percentages in those smaller than 60 mm. The ribs are only present in five categories with a higher frequency in the larger size ones (60–69 and 90–99 mm).

The fracture patterns were also analysed, taking into account shape, texture and angle in all the diaphyses fragments larger than 30 mm were 112 specimens. Then the fresh fracture index was calculated for each

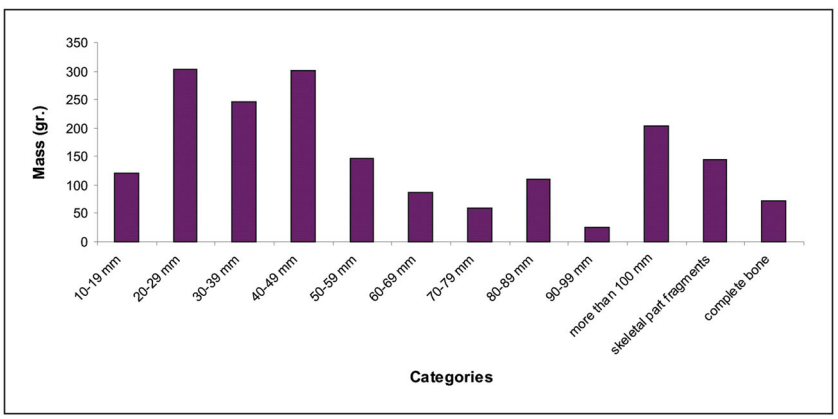

Figure 3. Bone fragments frequency sorted into size categories quantified by mass at La Primavera site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

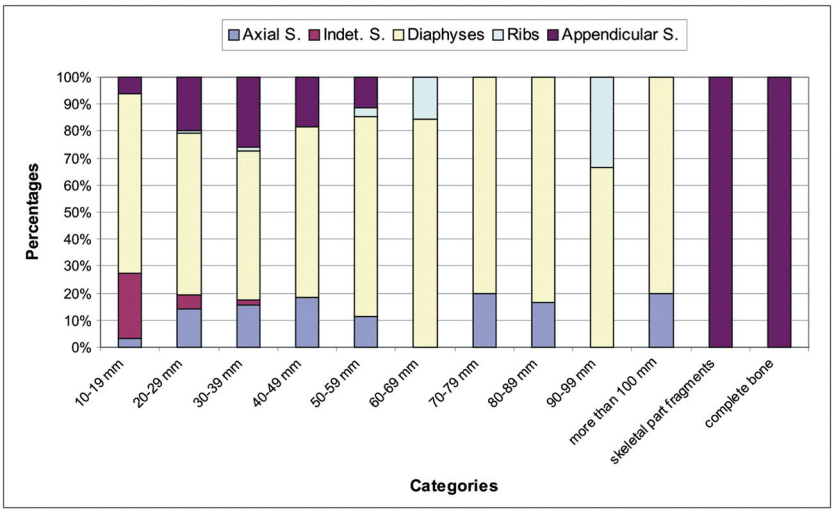

Figure 4. Proportion in which each type of bone is represented in each of the size categories at La Primavera site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

one of them. The larger frequency was found on specimens with 6 ($n = 24$) and 3 ($n = 23$) indexes, followed by those of 5 ($n = 17$), 4 ($n = 15$) and 1 ($n = 14$; Table 1; Figure 5). The average index of the assemblage was 3.5.

Loma Ruiz 1 site

Loma Ruiz 1 site is located in a dunes area, close to two lagoons, 35 km north from the Colorado River and 30 km away from the Atlantic shore (Figure 1). The initial field work (2001) involved surface gathering in a low dale close to the dune and three test units. As a consequence of this work, grinding artifacts, bony, lithic and ceramic materials were recovered, a fact that then derived in the excavating two units. As regards the site's functionality, the analysis that has been performed indicates that it would correspond to a multiple activity's base camp, briefly occupied during the initial Late Holocene (Stoessel, 2006, 2007; Martínez, 2008–2009). With regard to the chronology, there were two radiocarbon dates on the bones of guanaco, which provided ages of 1615 ± 50 and 1935 ± 44 BP. Later, two new samples of guanaco were dated, which provided ages of 1749 ± 64 and 1775 ± 66 BP. Consequently, the site would have been occupied during the period ca. 1900–1600 BP.

Table 1. FFI score of the bone fragments of La Primavera site

FFI	Frequency
0	8
1	14
2	11
3	23
4	15
5	17
6	24
FFI average	3.5

As regards the archaeofaunal assemblage, the materials recovered from the two units has been analysed in previous articles ($n = \sim 9000$; Stoessel, 2006, 2007). The analysis indicated that guanaco was the species with the highest frequency in the assemblage. As to skeletal parts representation, there is a predominance of appendicular skeleton, mainly long bones, whereas there are few axial skeleton elements. This fact suggests that the skeletal parts that were taken to the site were selected and that secondary processing and consumption took place there. Helicoidal fracture debris have been found as well as long bones (e.g. tibias, metapodials) with anthropic fracture that would indicate marrow consumption *in situ*. The %MAU frequencies of guanaco from this assemblage were correlated to the meat and marrow indexes for this species developed by Borrero (1990). The correlation was not significant. In this case, the coefficient is very low (Spearman's $rs = 0.0912$) and is associated with a high probability of no relationship ($p = 0.63171$). Therefore, the skeletal parts representation would not correspond to their economic potential, and that is to say, there was no intentional selection of the skeletal parts holding the higher produce. However, the correlations between %MAU frequencies of guanaco and bone mineral density were significant in this site. In this sense, the Spearman correlation coefficient showed

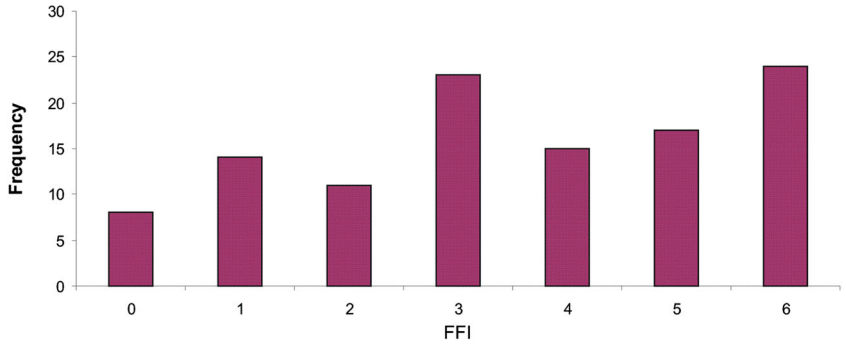

Figure 5. Fresh fracture index of the bone fragments of La Primavera site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

that the probability of the hypothesis of no relationship is practically zero ($p = 0.00048$), and the coefficient is quite high (Spearman's $rs = 0.5736$). Consequently, the absence of certain elements may also be explained by the action of postdepositional processes (e.g. roots actions and chemical deterioration; Stoessel, 2006, 2007).

The archaeofaunal assemblage presents a high degree of fragmentation, which would be partly due to human activities linked to carcass processing. The presence of helicoidal fracture debris and bones that present this type of fracture suggests that the fragmentation would be a consequence of guanaco secondary processing and consumption (bone marrow extraction) (Stoessel, 2006, 2007). The materials recovered from the two units (n = ~9000) were taken into account for the fragmentation levels and fracture patterns analysis.

Taphonomic analysis

The taphonomic analysis showed that this assemblage has been heavily affected by the chemical deterioration (36.32%) and the roots action (32.95%), two processes that may be interrelated. These processes modified a high percentage of bones producing in more severe cases the loss of the cortical surface. Consequently, differential preservation problems related to bone mineral density may be linked to these processes. A low percentage of specimens presented evidence of weathering (~5%), indicating that the remains did not stay a very long time on the surface. The low frequency of bones with evidence of weathering could be the result of reexposing a part of this assemblage product the dynamics of the dune. A low percentage of specimens also presented rodent marks (~7%). Evidence of other agents or processes that may have acted has not been detected (Stoessel, 2006, 2007).

Results

As regards the specimen's representation by size categories, there is a predominance of the two smaller ones, 10–19 mm (88%; $n = 1913$) and 20–29 mm (8.92%; $n = 194$). The frequency of bone elements is

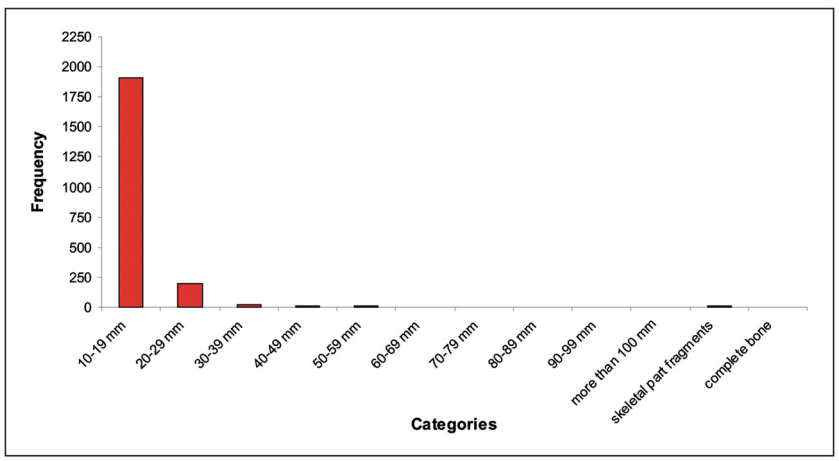

Figure 6. Bone fragments frequency divided into size categories at Loma Ruiz 1 site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

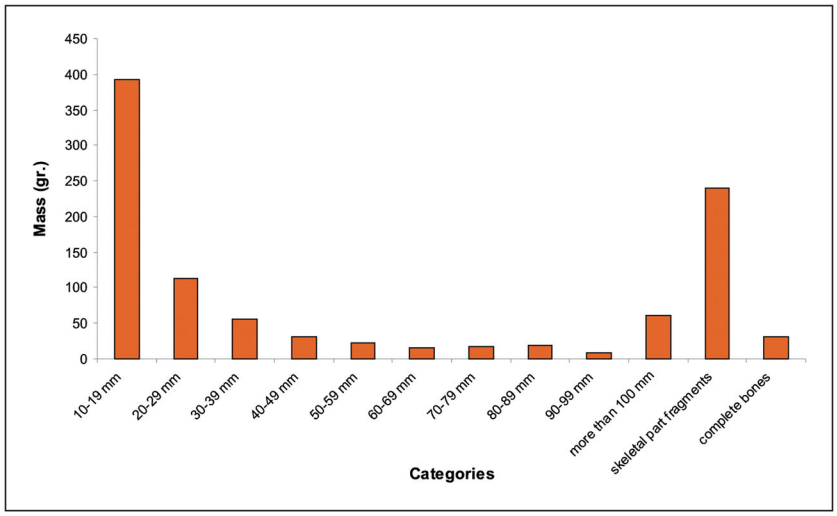

Figure 7. Bone fragments frequency divided into size categories quantified by mass at Loma Ruiz 1 site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

almost null in the other size categories except for categories 30–39 mm (1.14%; $n = 25$), 40–49 mm (0.50%; $n = 11$), 50–59 mm (0.27%; $n = 6$) and skeletal part fragments (0.45%; $n = 10$) (Figure 6).

When the quantification is performed taking the bone specimens mass into account (Figure 7), a different situation is observed. In this case, there is a predominance of smaller size category (10–19 mm) followed by skeletal part fragments, 20–29 mm and more than 100 mm. However, the predominance of the smaller size category yields evidence of the high degree of fragmentation of this assemblage.

As regards the proportion in which each type of bone is represented in the different size categories it can be observed that in all of them, except for skeletal part fragments and complete bones, there is predominance of diaphyses, and in those smaller than 60 mm, spongy axial and appendicular bones are variably represented through in a smaller frequency. The skeletal part fragments category is only represented by appendicular spongy bones (e.g. tibia and humerus distal epiphyses, radius, ulna and metapodials proximal epiphyses, etc.), whereas in the complete bone's category, spongy appendicular ones (e.g. patella) prevail, followed by axial spongy ones (e.g. caudal vertebra; Figure 8).

For the fracture pattern's analysis, a total amount of 47 specimens was taken into account. These correspond to the shaft fragments larger than 30 mm. As it can be seen in Table 2 and Figure 9, those that hold

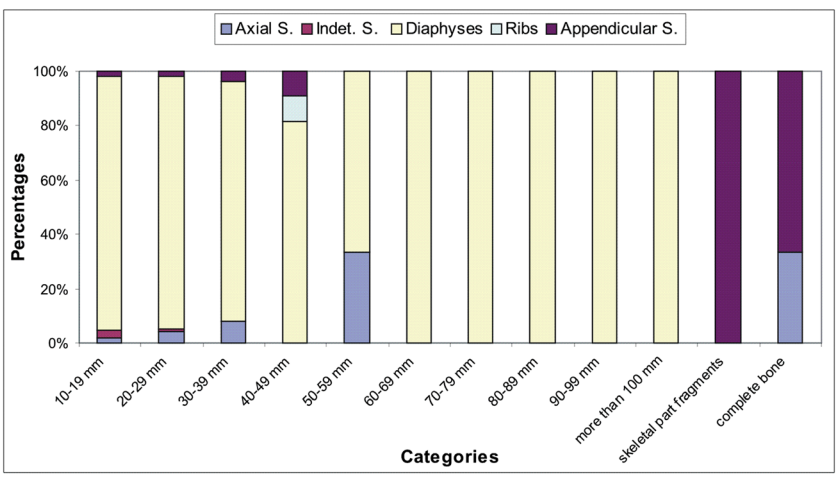

Figure 8. Proportion in which each type of bone is represented in each of the size categories at Loma Ruiz 1 site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

Table 2. FFI score of the bone fragments of Loma Ruíz 1 site

FFI	Frequency
0	10
1	7
2	3
3	11
4	8
5	4
6	4
FFI average	2.58

index 3 ($n = 11$) are the highest frequency ones, followed by those with index 0 ($n = 10$), 4 ($n = 8$) and 1 ($n = 7$). The indexes 5 ($n = 4$), 6 ($n = 4$) and 2 ($n = 3$) are represented by a smaller bone element's frequency. The average index of the assemblage is 2.58.

El Tigre site

El Tigre Site is located in a small deflated dunes area 200 m away from the old Colorado River right hand margin and between 15 and 20 km away from the Atlantic shore (Figure 1). Fieldwork began in 2003, and since then different activities have been performed that have included surface gathering and excavations in different areas of the low dales that constitute the site. These allowed the recovery of a great amount and diversity of bone, lithic and ceramic materials whose characteristics would indicate that this site would functionally correspond to a multiple activity's base camp. With regard to the chronology, four samples were dated, three of guanaco and a *Percichthys* sp., which provided ages of 536 ± 43, 455 ± 45, 437 ± 43 and 930 ± 47 BP. From these results, it was proposed that the site would have been reoccupied during 900–400 BP (Armentano, 2004; Stoessel, 2006, 2007; Martínez, 2008–2009; Martínez *et al.*, 2009b).

As regards the faunal remains, the recovered material from nine excavation units and four test units ($n = \sim 42\,000$) from the central low dale was analysed, and they yielded evidence on the existence of an important frequency and diversity of both terrestrial and fluvial species with exploitation evidence. Guanaco prevails among the terrestrial species, while regarding fish, the highest frequency corresponds to perch (*Percichthys* sp.). Almost all the guanaco skeletal parts are present, a fact that suggests that the complete prey was transported to the site, possibly in primary processing units, and that the secondary processing and consumption stages were performed *in situ*. The correlation between the %MAU frequencies of guanaco and the meat and marrow indexes were not significant. In this sense, the Spearman coefficient value obtained is negative (Spearman's $rs = -0.14705$) and is associated with a probability of no relationship between two variables rather high ($p = 0.43808$). This would indicate that there was no selectivity in favour of the parts that yield a higher economic profit. This would be expected if, as it was mentioned before, the complete carcasses were transported to the site (Stoessel, 2007).

The terrestrial species assemblage presents high fragmentation levels, a fact that was mainly considered to be a consequence of the human activities related to *in situ* processing of the carcasses. It was inferred that the high degree of fragmentation observed on the large amount of helicoidal fracture debris and guanaco long bone diaphyses would correspond to an intensive processing linked to this species bone marrow consumption. Besides, technological traits have been recorded on the bones, such as impact points and flakes (Stoessel, 2007). The faunal remains obtained from the central low dale nine excavation units ($n = \sim 41\,000$) are analysed in this article.

Taphonomic analysis

The results that were obtained indicate that one of the main processes that affected the assemblage was root's action, which was identified on 64.98% of the analysed

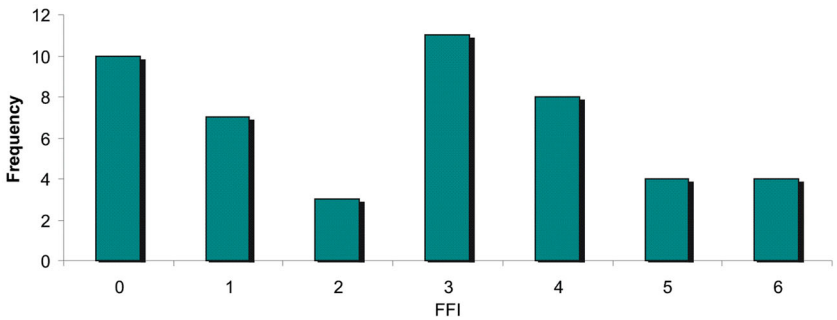

Figure 9. Fresh fracture index of the bone fragments of Loma Ruiz 1 site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

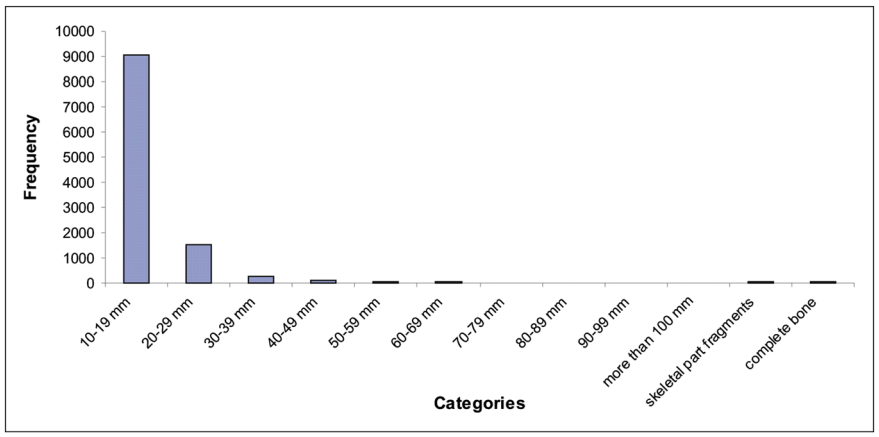

Figure 10. Bone fragments frequency divided into size categories at El Tigre site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

specimens. Weathering evidence was only recorded on 2.81% of the bone remains, which would mainly correspond to stage 1 (2.03%). This would indicate that the remains were buried quickly. Scarce evidence of other agents has been detected: rodent marks on 0.39% and carnivore marks on 0.06%. No evidence of other processes (e.g. trampling) was found. The correlation between the %MAU frequencies of guanaco and the bone mineral density was not significant. The Spearman coefficient value obtained (Spearman's $rs = 0.06714$) is quite low and is associated with a probability of the hypothesis of no very high relationship ($p = 0.8783$). This would indicate that there were no differential preservation problems in the assemblage (Stoessel, 2006, 2007; Martínez *et al.*, 2009b).

Results

On regards representation by size categories, the larger specimen's frequencies are those of smaller size: 10–19 mm (81.38%; $n = 9066$), 20–29 mm (13.60%; $n = 1516$) and 30–39 mm (2.12%; $n = 237$), whereas larger size ones are represented by a smaller number of elements: 40–49 mm (0.87%; $n = 97$), 50–59 mm (0.29%; $n = 33$), 60–69 mm (0.27%; $n = 31$), 70–79 mm (0.17%; $n = 20$), 80–89 mm (0.08%; $n = 9$), 90–99 mm (0.04%; $n = 5$), more than 100 mm (0.05%; $n = 6$). Very few bones have survived as skeletal parts (0.43%; $n = 48$) mainly appendicular epiphysis (phalanges, metapodials, humerus and tibias). The same situation is observed on complete bones (0.63%; $n = 71$); in this case, they are small bones such as sesamoids, phalanxes and tarsus (Figure 10).

Figure 11 depicts the fragment's distribution in mass quantified size categories. The categories that are smaller than 40 mm dominate the assemblage even when compared with complete bones, therefore indicating that fragmentation is important.

As regards each type of bone representation per category, in the smaller one's spongy appendicular and axial diaphyses fragments prevail. Diaphyses

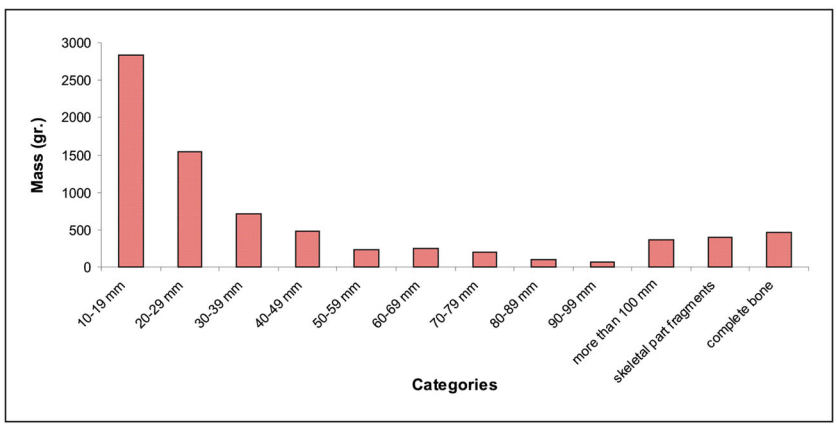

Figure 11. Bone fragments frequency divided into size categories quantified by mass at El Tigre site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

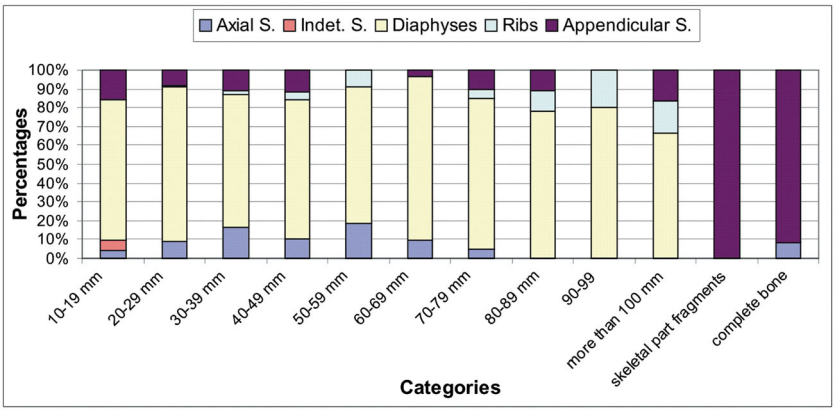

Figure 12. Proportion in which each type of bone is represented in each of the size categories at El Tigre site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

amply dominate the larger size categories, whereas appendicular and axial spongy one's representation is more variable. Ribs have a higher representation in the larger size groups. The skeletal part fragments category is only represented by appendicular spongy ones, and in the complete bone's category, appendicular spongy ones prevail followed by axial spongy bones (Figure 12).

Fracture pattern analysis was performed on a total amount of 319 specimens, which correspond to shaft fragments greater than 30 mm. As it can be observed on Table 3 and Figure 13, those with a 0 index ($n = 74$) are the ones which present a higher frequency followed by those that have 6 ($n = 47$), 4 ($n = 44$) and 1 ($n = 43$) indexes, whereas indexes 2, 3 and 5 are represented by a smaller number of bone specimens ($n = 37$). The average index of the assemblage is 2.74.

Discussion

The faunal assemblages of the analysed sites have been affected by the action of different agents and/or processes. In this sense, taphonomic analysis has shown that the acting processes have mainly been root action and, in a lesser degree, weathering, rodents and carnivores. These have modified, with different degrees of intensity, the bone surfaces. Consequently, grading criterions such as fracture surface texture may be conditioned by the modifications that were originated by their action. However, these agents and/or process incidence cannot account by them for the high degree of fragmentation that the assemblages present, and besides, evidence of other processes that may have generated it (e.g. trampling) has not been detected. Some of these agents and/or processes (e.g. abrasion, rodents) have acted with higher intensity at La Primavera and may have generated part of the bone remains fragmentation. Nevertheless, the characteristics of the assemblage would indicate that human action was also an important part in its conformation.

Table 3. FFI score of the bone fragments of El Tigre site

FFI	Frequency
0	74
1	43
2	37
3	37
4	44
5	37
6	47
FFI average	2.74

On the other hand, even when the assemblages that have been analysed come from different contexts (surface finds at La Primavera; stratigraphy at Loma Ruiz 1 and El Tigre) and had different taphonomic stories, applying the Outram (2001) methodology has proven to be useful to evaluate aspects connected to the consumption of nutrients such as guanaco bone grease and marrow and the intensity of their exploitation. The analysis performed at Loma Ruiz 1 and El Tigre has confirmed the tendencies that were previously posed as regards the high degree of fragmentation that they present. In this sense, size categories that are smaller than 40 mm amply dominate the assemblage at El Tigre site, both when they are quantified by the number of elements or by mass (Figures 10 and 11). At Loma Ruiz 1, smaller size categories are the ones that present the higher frequencies. Although when the quantification is performed taking into account the specimens mass, skeletal part fragments present the larger frequency, when all the categories are considered, the smaller size

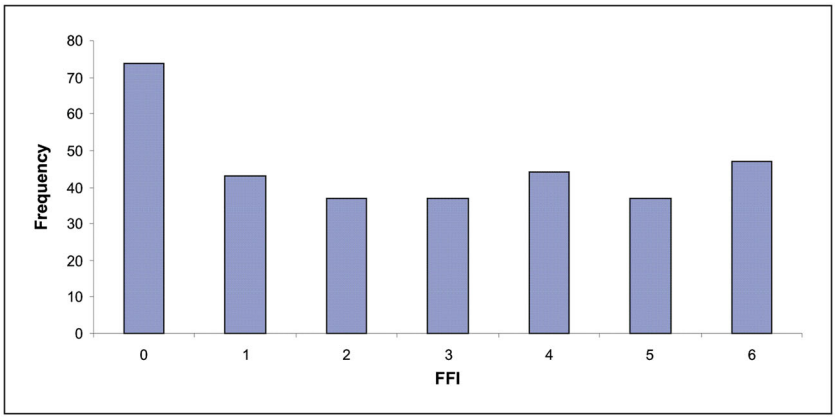

Figure 13. Fresh fracture index of the bone fragments of El Tigre site. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

ones prevail (Figures 6 and 7). At La Primavera, there is also a larger specimen frequency in the smaller size categories, a fact that would indicate that there is a high degree of fragmentation in this assemblage. However, the representation is more variable when the bone element's mass is taken into account (Figures 2 and 3). These results would indicate that there were differences in the guanaco exploitation intensity in the analysed sites.

As regards the representation of the different types of bones in the different size categories, at El Tigre the diaphyses fragments have higher frequencies both in smaller size categories as in larger size ones, followed by axial and appendicular spongy ones, although in those of larger size their representation is more variable. Spongy appendicular bones prevail in the skeletal parts fragments category as well as in the complete bone's category, followed in this last case, by spongy axial ones. If medullar and bone grease distribution in the skeleton is considered, this pattern would be expected in situations where both nutrients have been exploited. At Loma Ruiz 1, diaphyses amply prevails, whereas appendicular and axial spongy bones are represented in a smaller and more variable frequency in the smaller size categories. The skeletal parts fragment is only represented by spongy appendicular bones and in the complete bone's category, appendicular spongy ones prevail followed by axial spongy ones. This pattern may correspond to a marrow and probably bone grease exploitation for consumption. Notwithstanding, it must be considered that differential preservation problems related to bone mineral density aroused in this assemblage. In this sense, the specimen's representation may have been conditioned by postdepositional process action and not only by the consequence of practices related to processing and consumption. At El Tigre and, in a smaller frequency at Loma Ruiz 1 ceramic fragments with adhered substances and soot have been recovered (Stoessel, 2006, 2007; Martínez, 2008–2009) as well. The ceramic could have been part of the available technology used to obtain bone grease. At La Primavera, diaphyses present the highest frequency in all categories. Spongy appendicular bones are less frequent in the smaller size categories, whereas spongy axial ones are presented in almost every category in a smaller percentage.

Skeletal parts fragments and complete bones are only represented by appendicular spongy bones. This would correspond to bone marrow and grease consumption. An interesting aspect is the representation of the ribs. In the analysed assemblages, they are more represented in the larger size categories (Figures 4, 8 and 12). This is most remarkable at the El Tigre site. The presence of relatively undamaged ribs within a fragmented assemblage could be indicative of targeted fracture of more fat rich skeletal elements. Moreover, ribs representation supports the idea that although different postdepositional processes could generate some fragmentation, they were not mainly responsible for it, taking into account that ribs have lower bone mineral density values in comparison to the diaphyses. In Loma Ruiz 1 site, although the ribs are well represented in the middle-sized category (Figure 8) in the others category, the frequency is negligible. This may be related in part to the differential preservation problems mentioned.

As regards fracture patterns, at El Tigre, the specimens with index 0 dominate the assemblage. However, those with indexes 6, 5 and 4 also have an important frequency. At Loma Ruiz 1, specimens with index 3 are the ones that hold the largest frequency, followed by those with indexes 0, 4 and 1. Finally, at La

Primavera, the specimens with indexes 6 and 3 prevail, followed by those with indexes 5, 1 and 4. If these results and the fresh fracture indexes for each assemblage are taken into account (La Primavera, 3.5; Loma Ruiz 1, 2.58; and El Tigre, 2.74), it can be observed that at both El Tigre and Loma Ruiz 1, the largest part of the fragmentation took place when the bones were in a fresh state, while part of it occurred when the bones were dry. A different situation occurs at La Primavera. In the latter case, the dry fracture frequency is larger, a fact that may be related to the bone remains exposure because it is a surface site. However, as it was previously mentioned, the status of the preservation of bone remains must be taken into account because it can influence the variable's record and the scoring of each one of them.

On the other hand, it is necessary to consider that these indexes are sensible to the changes originated on the bones due to the application of treatments before culinary activities (e.g. cooking, boiling, etc.). To obtain bone grease, it is necessary to boil the fragments, a fact that may affect the conservation of the bone remains (Munro and Bar-Oz, 2005). In this sense, Outram (2002) conducted experimental work in which this index was tested on cattle bone remains by applying different treatments before the marrow extraction (freezing, boiling, exposure to the fire heat and warming up in the oven). The results showed that, in the case of boiled bones, the indexes oscillated between 2.34 (boiled for 10 min) and 4.58 (boiled for 1 h); that is to say, those specimens that were exposed to the heat for a longer period may show similar traces to those that are fractured when dry preferably. Besides, boiling may influence the preservation status of the bone remains because it weakens the bone structure and decreases its resistance to the action of mechanical forces (Munro and Bar-Oz, 2005). If it is taken into account that this technique is necessary to obtain bone grease and that this nutrient was part of the diet, its use may have influenced the preservation status of the specimens and consequently the resulting indexes. However, if all the assemblages are taken into account, at El Tigre, the specimens with indexes that are lower than 3 holds, on average, the largest frequency, a fact that would indicate that the biggest part of the fragmentation occurred when the bones were still fresh. Besides, as mentioned before, the technological traits that have been recorded on the bone remain would indicate anthropic origin, and these would have originated when the bones were fresh. The same occurs at Loma Ruiz 1, where specimens with indexes lower than 3 prevail. A different situation is observed at La Primavera. In this case, the average of specimens with indexes lower than 3 is similar to those that have higher indexes. Consequently, even if different treatments such as boiling may have influenced the specimen's status, an important part of the fragmentation would have occurred when the bones were dry. Besides, in some cases, certain characteristics of the fractures (e.g. colour) would indicate postdepositional origin.

Conclusions

If the different scenarios posed by Outram (2001) are taken into account as regards the exploitation of bone grease and marrow and the archaeological expectations that arise from them, the pattern found at El Tigre would correspond to a complete marrow extraction and possibly, in a lesser degree, bone grease extraction. As regards marrow consumption, all the bones that yield this product are fragmented. In this sense, the high frequency of long bone fractured diaphyses and splinters originated from fresh bones would indicate an intense exploitation for marrow consumption. This fragmentation is even observed in bones that yield a low amount of bone marrow such as phalanxes. Although some of them were found complete, a high percentage of them was found fractured. This could be linked to intensification in the exploitation of this nutrient. On the other hand, the high percentage of appendicular and axial spongy bones, of very small sizes in general, would indicate bone grease consumption. However, the presence of complete axial elements such as vertebras and spongy appendicular ones such as carpals, tarsus and sesamoids as well as the presence of appendicular epiphyses that would suggest that the exploitation of this nutrient would not have been as intense as in the case of the marrow. At Loma Ruiz 1, diaphyses prevails over the assemblage, and this would indicate exploitation for marrow consumption. Bones such as metapodials with anthropic fractures were also registered, and these mainly yield this product. With regard to the bone grease, the percentage of appendicular and axial spongy bones is too low to suppose their consumption. Besides, complete epiphyses (metapodials, humerus, tibia and radius) were also found, and this would indicate that, if it was exploited, its consumption was not intense. However, as it was mentioned in this article, there were differential preservation problems in the assemblage that may impose conditions on these inferences. With the information that has been obtained up to this moment, and taking into account the different scenarios posed by Outram (2001), Loma Ruiz 1 site pattern corresponds to a context where only marrow was exploited. The assemblage

at La Primavera site would correspond to marrow exploitation and in a lesser degree, bone grease. In this case, there are differences as regards the intensity of the exploitation. The characteristics of both assemblages would indicate that at El Tigre marrow processing for consumption would have been more intense (e.g. a great amount of helicoidal fracture debris and fresh fractured diaphyses) than at La Primavera. However, in both sites, a lesser intensity in the consumption of bone grease compared with bone marrow would have existed. These differences may be related to the characteristics of the occupations. Although the sites detected up to the moment in the area generally are multiple activity's base camps, those that correspond to the initial Late Holocene, such as La Primavera and Loma Ruiz 1, would be the resulting product of short ephemeral occupations, whereas those of the final Late Holocene, such as El Tigre, were long and there was occupational redundancy (Stoessel, 2006, 2007; Martínez, 2008–2009). The larger degree of intensity in the occupations towards the final part of the Late Holocene may have also reflected on a more intensive exploitation of some taxa (e.g. guanaco).

The information that was obtained in this article supports the tendencies posed for the subsistence model as regards the existence of intensification processes in the resource's exploitation towards the final part of the Late Holocene. The results obtained from this study indicate that guanaco was one of the species whose exploitation intensified (e.g. bone marrow and grease consumption) during this period. The analysis of these assemblages allowed discussing aspects that were not previously considered such as bone grease consumption. Applying this methodology to other faunal assemblages in the area with different chronologies and coming from different contexts would allow to explore the tendencies posed as regards the exploitation of this species and to evaluate in a more integral way the posed subsistence model. Finally, the methodology developed by Outram (2001) turned out to be adequate not only for the fragmentation levels and fracture patterns of these particular assemblages but also for the information derived from this analysis, which turned out to be useful to evaluate, together with other lines of evidence, the existence of an intensification process posed for the study area.

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