PROMETHEUS PRESS/PALAEONTOLOGICAL NETWORK FOUNDATION (TERUEL)

Journal of Taphonomy

2012

Available online at www.journaltaphonomy.com

VOLUME 10 (ISSUE 1)

Much More Than It Was Expected: Preservational Differences of Diaphysis and Epiphyseal Ends of Guanaco (*Lama guanicoe*) Long Bones in Southern Patagonia (Argentina)

Juan Bautista Belardi*

Universidad Nacional de la Patagonia Austral. CONICET. Campus Universitario Avda. Gregores y Piloto Lero Rivera s/n. (9400). Río Gallegos, Santa Cruz, Argentina

Diego Rindel

CONICET. Instituto Nacional de Antropología y Pensamiento Latinoamericano 3 de Febrero 1370. (1426). Ciudad Autónoma de Buenos Aires, Argentina

Tirso Bourlot

Instituto Nacional de Antropología y Pensamiento Latinoamericano 3 de Febrero 1370. (1426). Ciudad Autónoma de Buenos Aires, Argentina

Journal of Taphonomy 10 (1) (2012), 45-65.

Manuscript received 27 June 2012, revised manuscript accepted 26 October 2012.

In archeofaunal assemblages from different parts of the world there is a predominance of diaphysis over articular ends. This differential proportion of diaphysis over epiphysis also characterizes a considerable proportion of the faunal samples from Patagonia, especially those from caves and rockshelters. However, the assemblages recovered from open-air contexts in south Patagonia shows an inverse pattern: a predominance of the epiphysis over the diaphysis of guanaco (*Lama guanicoe)* long bones, contrary to the expectations derived from their respective bone mineral density (BMD) values. The archeofaunal information obtained from six open-air sites is presented and the pattern is evaluated and compared considering the diaphyseal and epiphyseal long bone structure, the densitometric values obtained by Stahl (1999) for South American camelids, the environmental characteristics related with the substrates (lacustrine clay and sand dunes) of the sites and the regional taphonomic information. It is proposed that in dynamic environments such as those here considered, the observed pattern is related to weathering/abrasion, acting differentially on the types and position of the tissues that form the diaphysis and epiphysis. When the diaphysis begins to open and fragment the fracture stops in the epiphysis. Such process would be accelerated in cultural contexts as a result of obtaining nutrients from long bones -considered of low

*E-mail: juanbautistabelardi@gmail.com

processing cost (*sensu* Marean & Cleghorn, 2003)- and blanks for artifacts, causes bone to be fractured. Besides, the lack of large carnivores in Patagonia is another important factor that would affect the differential representation on epiphysis over diaphysis. Similar results obtained on different substrates can sustain the expression of the pattern on a regional scale while indicating that it corresponds to open-air site contexts in general. Thus, the correlation between present elements and BMD would result in a partial tool to evaluate the integrity of archaeofaunas from Southern Patagonia open-air sites.

Keywords: SOUTHERN PATAGONIA, DIAPHYSIS/EPHYFISIS, OPEN-AIR SITES, BONE MINERAL DENSITY, WEATHERING/ABRASION.

Introduction

One of the main patterns obtained from zooarchaeological researches is related to the highest representation of long bone shaft fragments over articular ends. This is a robust pattern that has been observed regardless age and source of the assemblages, being identifiable both in old and new world contexts, and from the Lower Paleolithic to pastoral groups (Marean & Kim, 1998; Pickering *et al*., 2003; Yravedra & Domínguez-Rodrigo, 2009). Ethnoarchaeological results and experiences in natural contexts indicate that among the possible factors for this occurrence, we can find the activity of carnivores (Binford, 1981; Faith & Behrensmeyer, 2006; Faith *et al*., 2007; Marean & Cleghorn, 2004), the role of weathering and BMD - which is greater in diaphysis than epiphysis (Elkin, 1995; Lam & Pearson, 2004; Stahl, 1999), and human activity through the implementation of culinary practices. The latter involves the differential destruction of the epiphysis for nutrients (Binford, 1978, 1981; Enloe, 1993; Gifford-González, 1989; Outram, 2001). This pattern was also recognized in guanaco (*Lama guanicoe*) archaeofaunal assemblages from multicomponent stratified caves and rock shelters from Patagonia (among others, Borrero *et al*., 1998-1999; Bourlot *et al*., 2009; De Nigris, 2001; Mengoni Goñalons, 1999; Rindel, 2009; Savanti *et al*., 2005). However, the archaeofaunal assemblages recovered in open-air contexts of this region showed an inverse pattern: a predominance of the epiphysis over the diaphysis of the guanaco long bones, running counter to the expectations derived from their respective BMD values. This differential preservation, mostly related to large mammals, was already identified by Conard and colleagues in sand dune environments from South Africa (Conard *et al*., 2008).

The objective of this work is to discuss the possible causes of the differential preservation pattern observed in guanaco long bones of from open-air zooarchaeological contexts of Southern Patagonia. The possibility of this as the result of human behavior, taphonomic process or the interrelationship, is explored using different frames of reference (Binford, 2001) and evaluating the guanaco archaeofaunas from five sites located in different regions of Santa Cruz province, Patagonia, Argentina. The sites lay on different substrates. Three of them are on lacustrine clay sediments in the Perito Moreno National Park –PMNP- (Istmo lago Belgrano –ILB- and Lomadas Este Alero Destacamento Guardaparques –LEADG) and Pampa del Asador (Cerro Pampa 2- Ojo de Agua -CP 2 OA). The other three sites are dunes of the Lake Cardiel (Grippa Si Lito No -GSLN and La Siberia 5 -LS 5) and Lake Tar (Río Meseta 1 –RM 1) (Figure 1).

These sites were chosen in order to investigate different environments and substrates from regions that show marked contrasts in ecological terms (among others, elevation above sea level, precipitation) to assess the regional expression of the observed preservation pattern.

The obtained results are the basis for discussing different implications for the study of archaeofaunas. These are not only relevant to the archaeology of Patagonia but also contribute to the discussion of the problem on differential preservation of epiphysis and diaphysis. This issue was initially proposed by Binford (1988) and continued and extended by Marean and colleagues on the basis of the study of bone collections from Eurasia (among others, Bartram & Marean, 1999; Marean, 1995, 1998; Marean & Assefa, 1999; Marean & Cleghorn, 2003, 2004; Marean & Kim, 1998; Pickering *et al*., 2003; Yravedra and Domínguez-Rodrigo, 2009). These authors emphasize the importance of considering the diaphysis of long bones and not only the articular ends in the quantifications, as was done by Stiner (1998, 2005). It is important to point out that the Patagonian case here highlighted is completely different to the one observed in the Old World, suggesting that the role of local conditions should be considered while the faunal analysis is performed.

General frameworks of reference

Southern Patagonia, the studied regions and the guanaco

Southern Patagonia is characterized by a high environmental heterogeneity and low climate predictability (Endlicher & Santana Águila, 1988; Sturzenbaum & Borrelli, 2001). This situation is directly related to the strength and persistence of westerly winds as the southernmost of Patagonia is located in the anticyclone area of the South Pacific, which reaches the east of Patagonia after discharging most of the humidity at the western edge of the Andes. These winds are more intense during spring and summer, when they have a high drying power of the surface (Mazzoni & Vázquez, 2000). According to their elevation these regions can be discriminated in lowlands (250-300 masl) and highlands (+ of 900 masl), which has implications regarding seasonality due to temperature and snow load.

The low endorheic basin of Lake Cardiel (49° 00' S, 71º 45` W) is located approximately 300 masl and carries a low snow load. The weather is arid/semi-arid with an annual rainfall between 100 and 270 mm. The environment corresponds to a shrub steppe, Western Patagonia District, Patagonian province (Cabrera & Willink, 1980). This general framework also applies to the case of the lower basin of Lake Tar (250-300 masl).

The upper basin of the Perito Moreno National Park (47º 40 'S, 72 º 30' W) -between 900 and 1000 masl- includes the basins of the Lakes Belgrano, Nansen, Azara, Volcano, Mogote and Burmeister. The climate is temperate-cold and the annual rainfalls are between 200 and 400 mm. Due to the altitude and longitudinal differences, there are several environments within the Park area: mainly grass-shrub steppe and the Andean Nothofagus forest. The other highland area is the basalt plateau of the Pampa del Asador (48º S, 71º 30' W); a grassy steppe environment located at 1100 masl (Cabrera & Willink, 1973).

The guanaco was the main prey for hunter-gatherer populations along the whole occupation of Patagonia (among others, Borrero, 1990a; Mengoni Goñalons, 1999; Miotti, 1998). As a generalist herbivore, it is basically a grazer but it can also browse according to the offer of available food and the time of the year. It lives mostly in open places, occupying areas of steppe or prairie, even though it can make use of the forest habitat (Cajal & Ojeda, 1994; Montes *et al.*, 2000). Adult individuals have a weight average between 88 kg and 120 kg (Raedecke, 1978) while sex differences in body size are not significant. Its behavior may be described as seasonally territorial, though with exceptions related mainly to zones with water availability (Oporto, 1983). Three basic structures may be identified in guanaco wild populations: family groups, male groups and solitary individuals (Puig & Videla, 1995).

The composition of the bones and the bone mineral density

The bone matrix has a dual structure composed of organic (collagen and other proteins) and inorganic material (mineral) (Lyman, 1994). The collagen fibers form the matrix or structure in which the inorganic component -composed of hydroxyapatite crystals- is arranged. The mineral content (calcium and phosphorus) provides the hardness of the bones and their resistance or compressive strength whereas the fibrous organic portion provides their elasticity, flexibility and supply tensile strength (Pierce *et al.*, 2004). The arrangement of both parts on the bone governs the direction of the bone fracture (Johnson, 1985; Lyman, 1994; Miotti, 1998). The structural unit of compact tissue is the osteon or Havers system, consisting of blood vessels, collagen fibers, lymphatic vessels and arteries, which are longitudinally oriented to the axis of the bone (Lyman, 1994; Miotti, 1998). They are also accompanied with the collagen fibers arranged in the same direction leading the reaction of bone to stress (Davis, 1987; Johnson, 1985; Miotti, 1990-1992). This is the case of the diaphysis while the epiphysis is composed of trabecular bone. Both types of tissues differ in their density, porosity and arrangement of the collagen fibers (Lyman, 1994). When the bone is fresh this heterogeneous distribution of the different bone tissues allows fractures in the diaphysis to spread to the epiphysis, where the spongy tissue is stroked. There, the breakage is stopped due to the differential density and structure of the bone diaphysis, which causes a deviation in the wave of energy (Miotti, 1990-1992). While the osteons operates as a mechanical unit of the compact bone, moisture content is an important factor controlling the fracture. The fresh bone has a greater capacity for energy absorption which allows it to contain the stress, unlike those bones in a dry state or with a high degree of dehydration at the time of the fracture (Johnson, 1985, 1989). Thus, the dry bone behaves as a brittle inorganic material and can tolerate only a small amount of force before breaking. That is why weathering, which promotes loss of moisture in the bones, is a relevant variable (see Conard *et al.*, 2008). In this regard, Tappen (1969) and Tappen & Peske (1970) showed that the orientation of the crack lines and weathering fractures are generated during the process of drying and collapse of the element and they are related with the orientation of most collagen fibers. As indicated by Gifford-González (1989) and Shipman (1981), the loss of tension of the collagen fibers causes cracks perpendicular to the direction of thereof. This process would differentially affect epiphysis and diaphysis because the higher mineralization of the latter would make them more brittle (Lyman, 1994).

Another important variable in relation to the representation of skeletal parts is the

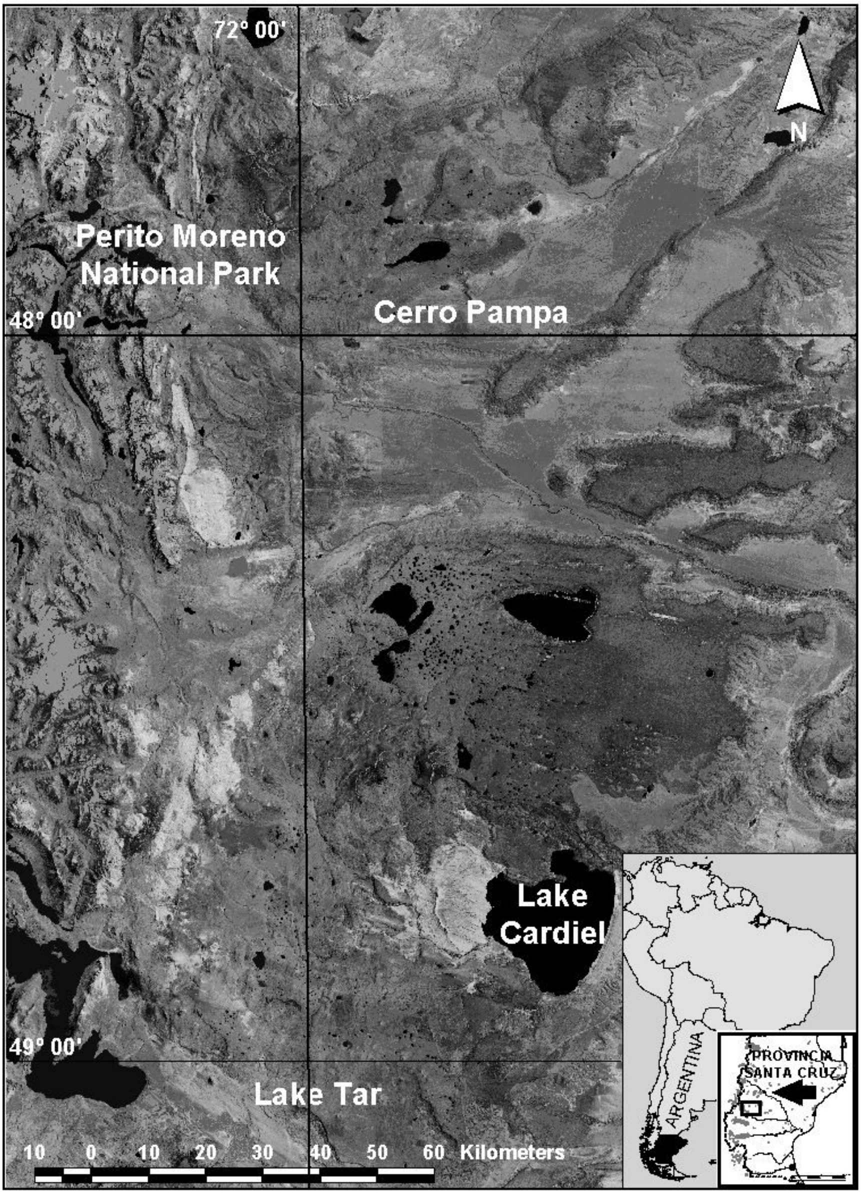

Figure 1. Map of the studied regions.

bone mineral density since this property shows variability between bones and its portions. This affects the potential for preservation of the elements involved (among others, Beherensmeyer, 1978; Lyman, 1994; Elkin, 1995; Ioannidou, 2003; Lam *et al*., 1999). In relation to the guanaco it has been shown that the ontogeny generates variability in BMD (Gutiérrez *et al*., 2010). Stahl (1999) established different scanning places for each of the bones of the South American camelids. For example, a proximal humerus with a fragment of attached diaphysis may have three density values. Thus, greater accuracy is achieved in understanding the process that makes the preservation of the present skeletal parts. The information provided by this author agrees with the values provided by other studies on BMD of South American camelids (Elkin, 1995) and with those obtained for other ungulates. These studies support the expectation that the more robust and harder parts of the different elements are the more resistant to taphonomic processes and likely to preserve (Ioannidou, 2003; Kreutzer, 1992; Lam *et al*., 1998, 1999). In this sense, Marean & Cleghorn (2003) postulated a model in which they proposed two sets of bones characterized by elements of high and low survival. This critical distinction is given by the higher density and lack of trabecular tissue, with high fat content in the diaphysis of the elements of higher survival. At the same time, the authors divide the process of destruction in nutritive and nonnutritive. The former is due to the action of animals attempting to obtain nutrients from the bones, while the latter is due to chemical and mechanical processes mediated by BMD.

Control measures have been proposed for the archaeofaunal assemblages considering the representation of proximal and distal ends of the humerus and tibia (Binford, 1981; Borrero, 1990a). As the proximal and distal ends of these elements are different in their BMD values, they are informative of the integrity of the assemblage. While this is a useful measure when there is no detailed taphonomic studies (see Barberena, 2008), it does not account for what happens to the diaphysis.

The regional taphonomic information

Observations were conducted in the basin of the Lakes Tar and San Martín (Belardi *et al*., 2010) where guanaco long bones from 10 guanaco skeletons deposited in open air settings and showing different weathering stages (sensu Behrensmeyer, 1978) were collected. These observations were complemented by those carried out on isolated bones as the regional archaeological research was developed. Weathering is considered to be the primary agent for generating variation in the states of preservation of the different elements. The marked differences in temperature that occur in southern Patagonia would collaborate with that process (see also Pasda, 2005:14). These observations were complemented in Pampa del Asador and in the Lake Cardiel basin, both on skeletons and isolated bones. It is important to emphasize that fractures on long bones were not caused by human action.

It is interesting to emphasize that in the case of the shaft, the cracks are produced according to the orientation of collagen fibers (Behrensmeyer, 1978; Tappen, 1969; Tappen & Peske, 1970) so they split in two pieces subsequently. It is important to note that some shaft pieces remain attached to one of the epiphyses, while others fall away as splinters (Figure 2). The explanation for the observed pattern would be related to the different position of the tissues that conforms

Figure 2. Different and progressive weathering stages on guanaco radius-ulnas.

the bony structure of the shaft, where the tissues follow the longitudinal axis of the bone. On the contrary, the fibers in the epiphysis are arranged transversely and are very flexible due to the presence of spongy tissue. So, when the shaft begins to open and to fragment according to that pattern, the destruction process stops in the articular joint because of the transversal position of the fibers respect to the bone axis. So it is expected that the weathering stages in long bones archaeofaunal samples diminish towards the epiphysis (Figure 2).

Methodology

The frequencies of guanaco long bones (humerus, radius ulna, femur and tibia) recovered at six open-air archaeological sites assemblages from lake basins and plateaus of southern Patagonia are analyzed and compared on the basis of NISP (Figure 1). This is carried out with the objective of finding whether the pattern aforementioned is a local feature or could have a regional character.

The diaphysis diagnostic zones, established on the base of topographic traits, were used for skeletal identification (Mengoni Goñalons, 1999). For NISP tallying, diaphysis counted as one only when they were found as isolated pieces of bone that could be assigned to a skeletal element. Certainly, this can lower the number of represented diaphysis given that the ones attached to the epiphysis were not considered but for evaluating the advance of fractures, fragmentation and the related weathering stages (see below). In the same vein, it is worth mentioning that all the studied sites have more diaphysis fragments than the ones recorded, but they were in an advance weathering stage that not allowed them to be recognized as any skeletal element. So, their remaining "fossil presence" was almost none. Long bone fragments were not assigned to diaphysis in a broad sense with the aim of getting a better understanding of the pattern of differential preservation by skeletal element.

In order to show the BMD differences in bones and their different segments, the values published by Stahl (1999) are used. Lam & Pearson (2004) have suggested the possibility that this methodology results in an underestimation of the shaft density because it does not consider the structural heterogeneity of the medullary cavity of long bones. However, in that case this aspect merely emphasizes the densitometric differences between diaphysis and epiphysis.

A comparative basis is established to evaluate whether there is a differential representation of epiphysis over diaphysis, considering that the fracture of the latter would generate at least, two longitudinal fragments, either as a natural or intentional fracture, for example, to obtain the bone marrow. Thus, ideally one would expect that the long bone fracture produces two diaphysiary segments and two epiphysiary ones. It must be noted that these numbers are much more than minimal for the diaphysis because the expectations derived from the experimental work performed by of Binford, where the long bones of caribou (*Rangifer tarandus*) -an ungulate as large as the guanaco- were fractured, shows markedly higher frequencies than the ones recently proposed (see Binford, 1978, 1988).

Table 1. Mean bone mineral density values for Camelid long bones (from Stahl, 1999)

Anatomic unit	Portion	Mean BMD
Humerus	Proximal	0.52
	Diaphysis	0.92
	Distal	0.89
Radius-ulna	Proximal	1.11
	Diaphysis	1.26
	Distal	0.81
Femur	Proximal	0.93
	Diaphysis	0.99
	Distal	0.66
Tibia	Proximal	0.65
	Diaphysis	1.43
	Distal	1.18

The shafts of the humerus, femur and tibia are the regions of highest BMD. The exception is the shaft of the radius ulna, whose value is placed after the olecranon (Stahl, 1999). However, in order to emphasize densitometric differences between epiphysis and diaphysis, the values of the scanned sites were averaged and grouped into three regions: proximal epiphysis, diaphysis and distal epiphysis. Based on the highest BMD of the diaphysis, the main expectation is that the epiphyses are more prone to destruction processes (Table 1). Furthermore, when each bone is considered separately, the higher BMD values of the distal end of the humerus and tibia are shown, the opposite occurs in the radius-ulna and femur.

Based on BMD values, the integrity of each bone in the different assemblages considering the percentage of representation of diaphysis and epiphysis were assessed. The purpose of this was to illustrate the degree of relative impact on BMD in the composition of the studied assemblages.

The other central point of this analysis is related to weathering, for which the stages appropriately described and defined by Beherensmeyer (1978) are used.

Archaeofaunal assemblages

The studied assemblages were recovered from the surface of open-air archaeological sites in lowlands and highlands, which show functional variability (Table 2 and Figures 1 and 3). In addition, the assemblages are mainly from different moments of the late Holocene (last 2500 years BP). Among the faunal materials, the ones from guanaco predominate. While there may be cases of contamination by the incorporation of modern bones, the presence of processing traces and the association with lithic materials support the human populations as the main agent of accumulation.

Highlands

Perito Moreno National Park (PMNP): Istmo Lago Belgrano (ILB), Lomadas Este Alero/rockshelter Destacamento Guardaparque (LEADG) sites

The ILB and LEADG sites (both on clay substrates of lacustrine origin) are in an environment of shrub steppe near to patches of Nothofagus forest (Rindel, 2009). They have been postulated to be of limited activities. The evidence supports the emphasis on the execution of the initial stages of the processing of guanacos. The frequency of limb bones is much higher than the axial skeleton, with the exception of the pelvic and shoulder girdles, which are present in important amounts.

The fragmentation index is low in both assemblages and a high frequency of modifications is recorded in association with the implementation of the perimeter marking technique and/or transverse fracture (this involves the preparation of the diaphysis by a complete or incomplete groove around the surface, so straight edges transversal to the long axis of the bone along with the separation of the articular ends of their diaphyseal segments are produced -Bourlot *et al*., 2009; Muñoz & Belardi, 1998; Rindel, 2009; Rindel *et al*., 2007).

The weathering profile is moderate to advanced, with most of the elements corresponding to stages 2 and 3 (Rindel, 2009).

Pampa del Asador (PA): Cerro Pampa 2 Ojo de Agua (CP 2 OA -PA) site

The Cerro Pampa Ojo de Agua (CP 2 OA) site is located on the plateau of the Pampa

Table 2. NISP per site considering each skeletal segment for each of the four long bones studied. References: px: proximal, dia: diaphysis, ds: distal.

	Highlands			Lowlands		
	PMNP (clay substrate)		Cerro Pampa (clay substrate)	Lake Cardiel (sandy substrate/ sand dunes)		Lake Tar (sandy substrate/ sand dunes)
Anatomic Unit	**ILB**	**LEADG**	**CP 2 OA**	**GSLN**	**LS5**	**RM 1**
Px	6	4	10	15	4	12
Humerus dia	31	15	7	9	2	21
Ds	44	6	39	22	7	23
Px	35	14	15	17	12	15
Radius-ulna dia	23	13	6	13	-	10
Ds	31	13	24	18	4	7
Px	19	7	27	11	12	11
Femur dia	10	15	13	14	1	6
Ds	28	5	19	11	2	15
Px	16	5	11	11	7	11
Tibia dia	8	7	12	22	-	15
Ds	26	7	25	12	5	6
Total	**278**	**111**	**208**	**175**	**56**	**152**

del Asador, in a shrub steppe environment (Rindel, 2009). Archaeological material lay on a clay substrate close to a spring. The archaeofaual assemblage also corresponds to the execution of limited activities, with an emphasis on the early stages of processing. It has been proposed for these upper areas a logistic and/or seasonal use during the late Holocene (Goñi *et al*., 2000-2002), in contrast to the use of lowland areas like Lake Cardiel, which has evidence of residential use during this time of occupation. The frequency of limb bones is much higher than that of the axial skeleton with the exception of the pelvic and shoulder girdles which have high values. The bone assemblage exhibits a high frequency of processing marks that belong to perimeter marking and/or transverse fracture (Bourlot *et al*., 2009; Rindel *et al*., 2007). As in the above cases of the PNPM, the weathering profile goes from moderate to advanced (Rindel, 2009).

Lowlands

<u>Lake Cardiel: Grippa Si Lito No (GSLN) and La Siberia 5 (LS5) sites</u>

The archaeological sites LS5 and GSLN are located on the eastern margin of Lake Cardiel, in an environment of sand dunes in the shrub steppe. The spectrum of activities carried out would be more extensive than the represented in the sites listed above. Zooarchaeological studies indicate that in both sites the activities conducted were dominated by the early stages of guanaco processing, dismembering and initial disarticulation (Bourlot, 2009; Savanti *et al*., 2005). The assemblages show high frequencies of upper fore and upper hind leg, with skulls also well represented in the case of GSLN. The level of the skeleton fragmentation is mostly low. There is also a high frequency of perimeter marking/transverse fractures in bones, which is consistent with their fresh and semi-fresh state (Bourlot, 2009; Bourlot *et al*., 2009). The samples show advanced weathering profiles (Bourlot, 2009).

<u>Lakes Tar and San Martín: Río Meseta 1 (RM 1) site</u>

The Rio Meseta 1 site lays on a sandy substrate at the east bank of Lake Tar, in the sub-shrub steppe (Belardi *et al*., 2010). Multiple activities would have been made there. The recovered archaeofaunal assemblage shows processing evidence (cut marks and percussion marks), among which include items that have perimeter marking/transverse fractures, indicating that at least a part of this sample is the result of human activity. The anatomical profile exhibits a low frequency of axial bone contrasting with the predominance of appendicular long bones. Considering the fragmentation state of the assemblage, long bones are extensively fractured. This is reflected in the high frequency of negative impact scars and perimeter marking. On the contrary, bones with cancellous tissue or portions where trabecular fat can be extracted are not entirely broken. In this sense, the percentage of complete bone reaches 69%. The weathering of the assemblage is moderate to advance.

Results

The retrieved information on the sites for each of the long bones studied is presented in Table 2 and their percentage of epiphysis and diaphysis in Figure 4.

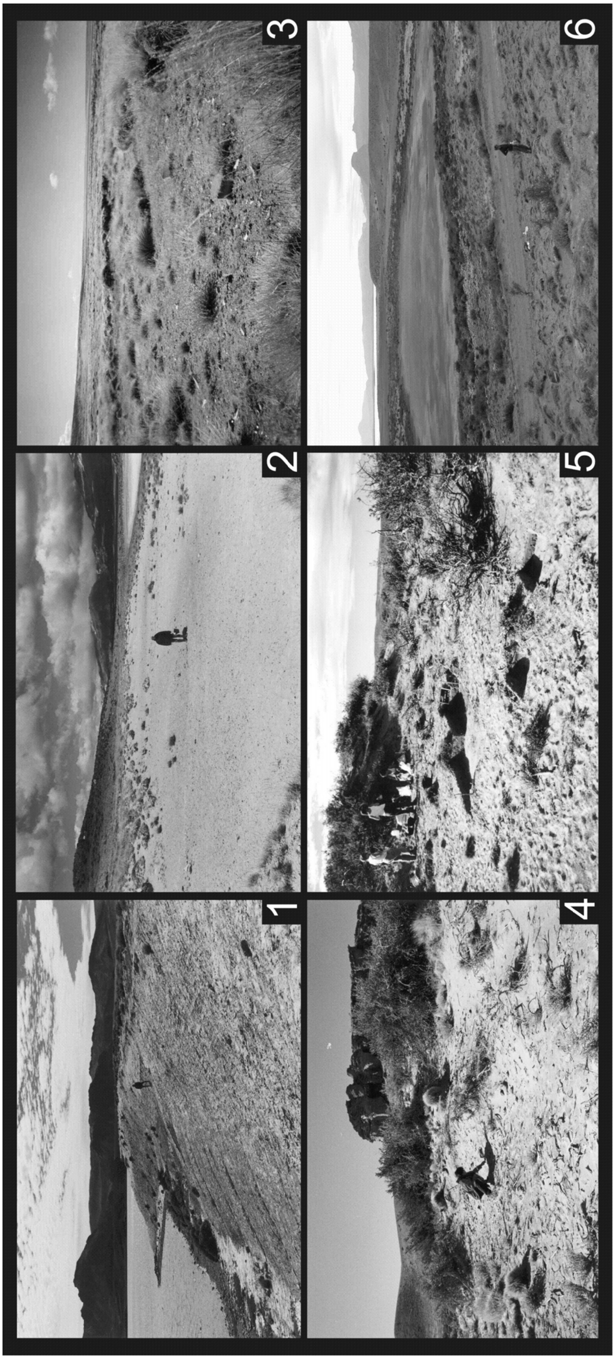

Figure 3. The archaeological sites. References: 1- Istmo Lago Belgrano (ILB), 2- Lomadas Este Alero/rockshelter Destacamento Guardaparque (LEADG), 3- Cerro Pampa 2 Ojo de Agua (CP 2 OA), 4- Grippa Si Lito No (GSLN), 5- La Siberia 5 (LS 5) and 6- Río Meseta 1 (RM 1).

In most of the analyzed sites there is a predominance of the epiphysis of guanaco long bones over the shaft fragments (Figure 4). If it is expected, as proposed, that two fragments were set at least from a fractured/ broken diaphysis. So, the frequency of shaft recorded must be markedly greater, but to the contrary in 70.8% of the cases one of the two epiphyses prevails and in all cases but one (the humerus in PMNP) there are more epiphysis than shafts ($X^2_{Test} = 321.24$; $X^2_{0.05, v=23} = 35.17$). Therefore, the expectation derived from the BMD values cannot be hold. Nevertheless, problems of differential preservation would be recorded in relation to the proportion of the epiphysis, since in all assemblages the elements with greater BMD tend to preserve. Thus, the humerus is the one that fulfils the expectation of a greater representation of its distal epiphysis. Meanwhile, with the exception of site CP 2 OA, in the radius-ulna, the proximal epiphysis predominates, although the differences are not as obvious as in the humerus. The representation of femurs is more variable, as in the case of the site LS5 which best fits the expectation of the BMD. With the exception of site RM1, the tibia fulfils the expectation of a greater representation of the distal epiphysis.

The average length of the diaphysiary fragments ranges from 87 to 104 mm (Table 3), which has collaborated with its identification. The representation of specimens with little impact of weathering is very low and its highest incidence is reflected in Stages 2 and 3, emphasizing that in all sites there are specimens in stage 4 (Table 3). On this basis, it can be argued that the identifiable threshold markedly decreases from stage 4.

The indicated trends show not only a higher frequency of epiphysis over diaphysis in all the studied sites but also variability in the proportional preservation between proximal and distal epiphysis. Thus, it can be argued that there is variability in the incidence of BMD-mediated factors that would be acting in the conformation of the archaeofaunal profiles from the sites. Internal variations in the weathering stages of the shafts and assemblages in general would be related to

Table 3. Diaphysis percentages according to their weathering stages (including the four long bones studied) and mean length of splinters per site.

	Highlands			**Lowlands**		
	PMNP (clay substrate)		**Cerro Pampa (clay substrate)**	**Lake Cardiel (sandy substrate/ sand dunes)**		**Lake Tar (sandy substrate/ sand dunes)**
Weathering stages (%)	**ILB**	**LEADG**	**CP 2 OA**	**GSLN**	**LS5**	**RM 1**
0	1.09	3.55	0.17	10.89	0	0
1	8.32	16.12	5.33	9.9	0	15
2	30.14	35.79	40.96	29.7	66.66	63
3	36.89	37.97	40.96	29.7	0	13
4	24.57	6.28	12.4	17.82	33.33	8
5	0	0.27	0.51	1.98	0	0
Mean length of splinters (mm)	104.15	96.87	87.46	87.63	87.8	100.21

the moment of interception by the archaeologists, as it is discussed below.

Discussion

In the analyzed sites from PNPM, Cerro Pampa and the lower basins of the Lakes Cardiel and Tar there is a predominance of the articular ends of guanaco long bones over the diaphysis fragments. This pattern, which considers the functional diversity of sites as well as the environmental and ecological variability of their areas, can be extended to other open-air settings in sandy and clay substrates from southern Patagonia.

What is the reason for this pattern? The answer should consider both cultural and natural aspects. In the first case, with a broken long bone few shaft fragments would be generated as they may be attached to each of the epiphysis. A second possibility, complementary to the first one, would be related to the transport of the shafts after the epiphyseal removal. Finally, the intense processing of the epiphyses to remove the bone marrow, for example, may cause a failure in the analytical recognition (see Enloe, 1993).

All these possibilities could have happened in the studied archaeological contexts. However, although the fracture of the bone would leave the shaft attached to the epiphysis, they would follow the destruction pattern observed in the taphonomic samples: from the diaphysis to the epiphysis, in this way, the latter would continue to predominate. The case of the transport of the shaft is difficult to assess, so still remains as a possibility. Nevertheless, the evidence indicates that, at least some of them have remained at the site. The intense processing of the diaphysis to obtain the bone marrow may be supplemented with the available on the articular ends (Outram, 2001; see Bourlot, 2009 for cases in southern Patagonia), generating a very low anatomical identification of the archaeofaunal assemblages; although in these sites the processing has been concentrated on the diaphysis (Belardi *et al*., 2010; Bourlot, 2009; Rindel, 2009). A fourth possibility is the use of epiphysis as bone tools -pounders- (Hajduk & Lezcano, 2005). So, human manipulation may delay the decline of the bone. However, the frequency of such tools in most of the analyzed assemblages is low (Belardi *et al*., 2010; Bourlot, 2009; Bourlot *et al*., 2009; Rindel, 2009). Thus, although there are cultural aspects related to the processing and use of the bones that could have generated the observed profiles, they not totally explain the pattern.

Sandy and clay sediments are generally alkaline, a condition for a good preservation of the bone material (see Belardi *et al*., 2007). However, these are deposits whose dynamic is controlled by the sediment supply, the intensity and variation of wind direction, topography of the area, soil formation and vegetation. In southern Patagonia the processes of erosion and deposition are almost continuous, making cycles of exposure and burial of archaeological materials (among others, Bourlot, 2009) that threaten the stability of the bone specimens (see Conard *et al*., 2008; Guichon *et al*., 2000; Massigoge *et al*., 2010).

Archaeological deposits are affected by the absence of vegetation cover to the extent that, by deflation, lithics and bones are re-exposed on surface. When these processes are intense, the bones are deposited on a matrix of clay/dry sand, increasing the moisture loss from the bones. In this sense, the high temperature that the surfaces of the sites reached in summer by direct exposure to sun and wind action would also affect the

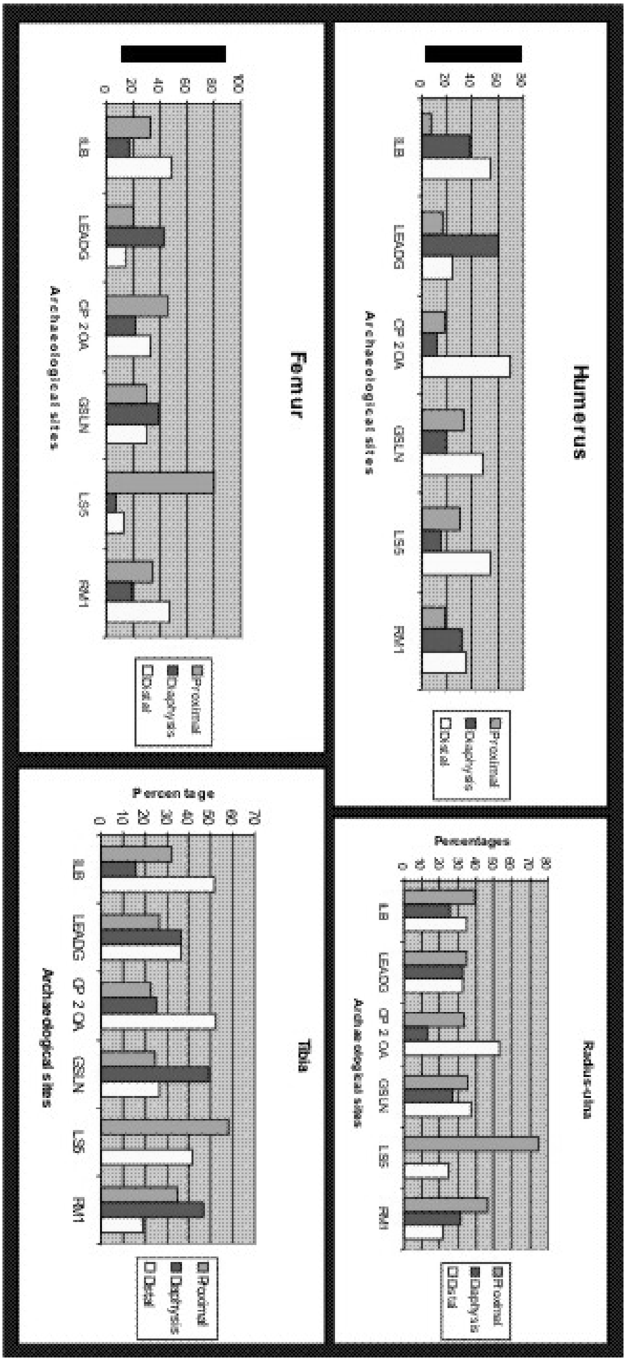

Figure 4. Percentages of epiphysis and diaphysis for each of the four long bones studied.

bones, accelerating the drying process (Conard *et al*., 2008; Johnson, 1985). This would cause the rapid decline of one of the main features of the bones, flexibility and, thus, the resistance to stress. The point is whether the diaphysis loss its moisture content faster than the epiphysis or whether they present lower moisture values as a fresh bone. In addition, wind action on clay and sandy substrates generates abrasion, helping to destroy those bones that already were fragmented by weathering. Genniesse (1982, in Lyman, 1994:86) studied the abrasion caused by sand particles on the bones and, even when the results were not statistically significant, he noted that more osseous tissue was removed when an abrasive force is perpendicularly applied to the grain bone than when it was applied in parallel, in which case the bone element tends to erode into smaller fragments. Taphonomic observations suggest that diaphisis are the first to suffer fractures when exposed to open-air conditions, indicating that dehydration occurs faster. They begin to fragment (peel and crack) following the natural line of the collagen structure into the epiphysis. It should be noted that the epiphysis keep together the “vectors of collagen fibers". As diaphysis open, more surface area is exposed to weathering and abrasion, which accelerates the process of exfoliation of the surfaces and the deepening of cracks. The corollary of this development is the gradual loss or disappearance of diagnostic features of the diaphysis and the conservation of the epiphysis (see Figure 2). Thus, the articular ends can become highly weathered but still be identifiable to certain extent. Therefore, in those specimens where there is a shaft segment attached to the epiphysis, weathering would decrease towards the latter (Belardi *et al*., 2010). Moreover, human population needs for the nutrients contained in the medullar cavities of long bones as well as for blanks for bone tools, cause the fracture of the diaphysis. The cooking of the different elements, add a further impact factor that changes the morphology of the collagen fibers, even with the presence of flesh and moderate temperatures (Koon *et al*., 2003).

The above findings provide new elements of analysis to previous models that discuss different lines of assessment of the preservation potential of archaeofaunal remains (see Cruz, 2007, for a Patagonian case study). They show substantial differences with recovered assemblages in caves and rockshelters; where archaeofaunal materials are not directly exposed to solar radiation, the chances of abrasion are less and their moisture remains relatively constant.

In the same way, variation is introduced into the model proposed by Marean & Cleghorn (2003, 2004) within the set of high survival elements. The bibliography of the Old World is prolific in cases in which the scarce survival of the articular ends is mediated by the activity of carnivores, since these parts retain nutrients for a long time after being used and discarded by humans and, therefore, become attractive resources to scavengers. An important issue is that in the Old World carnivore/scavenger niches are composed of animals capable of producing a high degree of bone modification (Binford, 1981; Marean & Cleghorn, 2007). This is not the case for the Holocene Neotropical animal communities, where carnivores were not able to introduce significant distortions in the frequency of skeletal parts of carcasses left by humans (Mondini & Muñoz, 2008). In Patagonia the only large carnivore is the puma (*Felis concolor*) that rarely has a scavenger behavior. Instead it is characterized as a hunter who occasionally consumes completely their prey (Borrero & Martín, 1996; Borrero *et al.*, 2005; Mondini & Muñoz, 2008). Moreover, in Southern Patagonia there are two species of foxes, Patagonian red fox and South American grey fox (*Pseudalopex culpaeus* and *P. griseus*, respectively). Although both species include carrion in their diet (Silva *et al.*, 2005; Zapata *et al.*, 2005), their small size greatly inhibits a significant degree of bone destruction on large prey (Borrero, 1990b, 2002; Martin, 1998, 2006). Thus, the absence of a scavenging behavior for the puma and the size of carnivores involved are other factors contributing to the preservation of the epiphysis.

Conclusions

In open-air archaeological sites like ILB, LEADG, CP 2 OA, GSLN, LS5 and RM 1 the expectations for bone preservation according to densitometric values are not completely fulfilled, as was observed in the differential representation of diaphysis and epiphysis, regardless the methodology for BMD calculation (see for example Elkin, 1995 vs. Stahl, 1999). The articular ends, of lower BMD, have a greater potential for survival in the environments (highland and lowland settings) and substrates (clay and sand) here recorded (see Tables 2 and 3). This does not necessarily indicate that the bone assemblages are well preserved, but there are parts that survive better than others, even when it has been shown that BMD varies with the ontogeny of the guanaco (Gutiérrez *et al.*, 2010; Massigoge *et al.*, 2010). In these cases, differences in the proportional representation of epiphysis of a same element seem to be informative (Binford, 1981; Borrero, 1990a).

Thus, the results of the correlation between NISP/MNE values and BMD at open-air sites can be misleading. Therefore, before explaining the absence of diaphysis shafts by cultural reasons in relation to transportation, processing, handling and consumption, natural causes should be considered. These results corroborate those obtained by authors such as Lam & Pearson (2004), Faith & Behrensmeyer (2006), Faith *et al.* (2007), and Conard *et al.* (2008) indicating that, regardless of the BMD, other variables such as depositional environment and the size, shape, strength, thickness of the cortex and hardness of bones must be considered when establishing the survival rate of the different segments.

It is suggested that differences in the representation of diaphysis and epiphysis in different open-air contexts of Patagonia would be related both to the time of interception of the assemblages by archaeologists and differences owing to hunter-gatherer decisions. In this sense, further observations on long bone destruction processes in Patagonia actual settings are still needed, since in complex contexts, cultural and natural factors have been important. The process would begin with humans breaking bones for marrow, using for such purpose control fracture techniques like perimeter marking/transverse fracture (Rindel, 2009; Rindel *et al.*, 2007, 2009; Bourlot *et al.*, 2009). The result of the implementation of these techniques would leave the articular ends separated from diaphysis fragments. From this, a differential destruction process would be produced, primarily affecting the diaphysis fragments. Burial and re-exposure of bones along the depositional history of the assemblages would collaborate to accelerate this process of differential destruction which ends with shaft fragments so destroyed that they would be no longer identifiable, together with fragments of articular ends that still retain their diagnostic features.

The archaeological implications of the information here discussed are important because they positioned open-air sites within a larger framework where complete bones or shaft fragments could be present, but there are factors that produce differential preservation of the articular ends, contrary to expectations derived from BMD values. Thus, the quantification of archaeofaunal open-air assemblages will tend to focus on them. This is not necessarily followed from arguments presented by Stiner (1998, 2005) or impair the value of the results achieved by Marean and colleagues (among others, Bartram & Marean, 1999; Marean, 1995, 1998; Marean & Assefa, 1999; Marean & Cleghorn, 2003, 2004; Marean & Kim, 1998; Pickering *et al*., 2003). We extend the range of variability known on processes that lead to differential preservation of skeletal remains, as well as contributed to establishing methodological care for quantification. These are results obtained on the basis of bone structure knowledge -arrangement and type of fibers, moisture content-, and depositional and substrate contexts at open-air sites, like direct exposure to changes in temperature, abrasion and absence of large carnivores. The results also allow the refining of previous models and have implications for discussions on archaeofaunas integrity and quantification. At the same time, they provide new references to evaluate comparisons between assemblages from open-air contexts and stratigraphy in Patagonia. Finally, it is necessary to emphasize the relevance of the issues raised for the case of environments with unsaturated niches of carnivore and with little capacity for destruction of the epiphysis, such as South America, Oceania and Madagascar.

Acknowledgements

We fully appreciate the helpful comments and suggestions offered by María Gutiérrez, Gustavo Barrientos, Ramiro Barberena, Luis Borrero, Flavia Carballo Marina, Cristian Kaufmann and Gustavo Martínez to earlier versions of the manuscript. Patricia Campan also helped improving the translation to English and Juan José Concetti answered questions on statistics. Finally, Charles Egeland helped us to sharp some thoughts. We thank them all. Our field work can be done due to the help provided by the owners and workers of the estancias from the Perito Moreno National Park, Pampa del Asador and the Lake Cardiel, Tar and San Martín basins. Research is performed with the support provided by grants from the Universidad Nacional de la Patagonia Austral (UNPA-UARG A/183/2, A/213-1), CONICET (PIP 6405, 0122), PICT 1247 and ANPCyT (26295).

References

Barberena, R. (2008). *Arqueología y biogeografía humana en Patagonia Meridional*. Sociedad Argentina de Antropología, Buenos Aires.

Bartram, L.E. & Marean, C.W. (1999). Explaining the "Klasies Pattern": Kua Ethnoarchaeology, the Die Kelders Middle Stone Age archaeofauna, long bone fragmentation and carnivore ravaging. *Journal of Archaeological Science,* 26 (1): 9-29.

Behrensmeyer A.K. (1978). Taphonomic and ecologic information from bone weathering. *Paleobiology,* 4 (2):150-162.

Belardi, J.B., Bourlot, T.J. & Rindel, D. (2010). Representación diferencial de diáfisis y epífisis de huesos largos de guanaco (*Lama guanicoe*) en contextos arqueológicos de médanos en Patagonia austral: el sitio Río Meseta 1 (lago Tar, provincia de Santa Cruz). In (Gutiérrez, M.A., De Nigris, M., Fernández, P.M., Giardina, M., Gil, A.F., Izeta, A., Neme, G. & Yacobaccio, H.D., eds.) *Zooarqueología a principios del siglo XXI: aportes teóricos, metodológicos y* *casos de estudio.* Buenos Aires: Ediciones del Espinillo, pp. 119-131.

Belardi, J.B., Bregliani, M., Rindel, D., Bourlot, T. & Gómez, H. (2007). Condiciones de preservación de conjuntos arqueofaunísticos en la meseta del Strobel (Provincia de Santa Cruz, Argentina). In (Morello, F., Martinic, M., Prieto, A. & Bahamonde, G., eds.) *Arqueología de Fuego-Patagonia. Levantando Piedras, Desenterrando Huesos… y Develando Arcanos*. Punta Arenas: Ediciones CEQUA, pp.411-419.

Binford, L.R. (1978). *Nunamiut Etnoarchaeology*. Academic Press, New York.

Binford, L.R. (1981). *Bones: Ancient Men and Modern Myths*. Academic Press, New York.

Binford, L.R. (1988). Fact and Fiction about the *Zinjanthropus* Floor: Data, Arguments, and Interpretations. *Current Anthropology,* 29: 123-135.

Binford, L.R. (2001). *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Hunter-Gatherer and Environmental Data Sets*. University of California Press, Berkeley.

Borrero, L.A. (1990a). Fuego-Patagonian Bone Assemblages and the Problem of Communal Guanaco Hunting. In (Davis, L.B. & Reeves, B.O.K., eds.) *Hunters of the Recent Past.* London: Unwyn Hyman, pp. 373-399.

Borrero, L.A. (1990b). Taphonomy of guanaco bones in Tierra del Fuego. *Quaternary Research,* 34 (3): 361-371.

Borrero, L.A. (2002). Taphonomic longitudinal studies in Tierra del Fuego. In (Gutiérrez, M.A., Barrientos, G., Mengoni Goñalons, G., Miotti, L. & Salemme, M., eds.) *Taphonomy and Zooarchaeology in Argentina.* British Archaeological Reports, 1601: 219-233.

Borrero, L.A., Franco, N.V., Carballo Marina F. & Martín F.M. (1998-1999). Arqueología de Estancia Alice, Lago Argentino. *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano,* 18:31-48.

Borrero, L.A. & Martín, F.M. (1996). Tafonomía de carnívoros: un enfoque regional. In (Gómez Otero, J., ed.) *Arqueología. Solo Patagonia.* Puerto Madryn: CENPAT-CONICET, pp.189-206.

Borrero, L.A., Martín, F.M. & Vargas, J. (2005). Tafonomía de la interacción entre pumas y guanacos en el Parque Nacional Torres del Paine, Chile. *Magallania,* 33 (1): 95-114.

Bourlot, T.J. (2009). *Zooarqueología de sitios a cielo abierto en la cuenca del lago Cardiel, Provincia de Santa Cruz: fragmentación ósea y consumo de grasa animal en grupos cazadores-recolectores del Holoceno tardío*. Unpub. PhD. Facultad de Filosofía y Letras, Universidad de Buenos Aires.

Bourlot, T.J., Rindel D.D. & Aragone A. (2009). La fractura transversa/marcado perimetral en sitios a cielo abierto durante el Holoceno tardío en el noroeste de Santa Cruz. In (Salemme, M., Santiago, F., Álvarez, M., Piana, E., Vázquez, M. & Mansur, E., eds.) *Arqueología de Patagonia: una Mirada desde el Último Confín*. Ushuaia: Editorial Utopías, pp.693-706.

Cabrera, A.L. & Willink, A. (1973). *Biogeografía de América Latina*. Secretaría General de la Organización de Estados Americanos. Monografía 13, Serie de Biología. Washington.

Cajal, J.L. & Ojeda, R.A. (1994). Camélidos Silvestres y Mortalidad por tormentas de nieve en la cordillera frontal de la Provincia de San Juan, Argentina. *Mastozoología Neotropical,* 1(1): 81-88.

Conard, N.J., Walker S.J. & Kandel A.W. (2008). How heating and cooling and wetting and drying can destroy dense faunal elements and lead to differential preservation. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 266: 236-245.

Cruz, I. (2007). The recent bones of the Rio Gallegos Basin (Santa Cruz, Argentina) and their preservation potencial. In (Gutiérrez, M.A., Barrientos, G., Mengoni Goñalons, G. Miotti, L. & Salemme, M., eds.) *Taphonomy and Zooarchaeology in Argentina*. British Archaeological Reports, 1601: 161-170.

Davis, S.J.M. (1987). *The archaeology of animals.* Yale University Press, New Haven.

De Nigris, M. E. (2001). Patrones de procesamiento final y consumo del guanaco en Patagonia. In (Mengoni Goñalons, G.L.. Olivera, D.E. & Yacobaccio, H.D., eds.) *Zooarqueología de Camélidos 3 El Uso de los Camélidos a través del Tiempo*. Buenos Aires: Grupo Zooarqueología de Camélidos, pp. 9-28.

Elkin, D.C. (1995). Volume density of South American camelids skeletal parts. *International Journal of Osteoarchaeology,* 5 (1): 29-37.

Endlicher, W. &Santana Águila, A. (1988). El clima del sur de la Patagonia y sus aspectos ecológicos. Un siglo de mediciones climatológicas en Punta Arenas. *Anales del Instituto de la Patagonia (serie Ciencias Naturales),* 18: 57-86.

Endlicher, W. & Santana Águila, A. (1997). El invierno de 1995: un fenómeno climático muy severo en la Patagonia austral. *Anales del Instituto de la Patagonia (serie Ciencias Naturales),* 25: 77-88.

Enloe, J. (1993). Ethnoarchaeology of Marrow Cracking: Implications for the Recognition of Prehistoric Subsistence organization. In (Hudson, J., ed.) *From Bones to Behavior. Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations. Souhtern Illinois University at Carbondale. Ocasional Paper 21, pp. 82-97.

Faith, J.T. & Behrensmeyer, A.K. (2006). Changing patterns of carnivore modification in a landscape bone assemblage, Amboseli Park, Kenya. *Journal of Archaeological Science,* 33 (12): 1718-1733.

Faith J.T., Marean C.W. & Behrensmeyer, A.K. (2007). Carnivore competition, bone destruction and bone density. *Journal of Archaeological Science,* 34 (12): 2025-2034.

Gifford-González, D. (1989). Ethnographic Analogues for Interpreting Modified Bones: Some Cases from East Africa. In (Bonnichsen, R. & Sorg, M., eds.) *Bone Modification*. Orono: Center for the Study of the First Americans, University of Maine, pp.179-246.

Goñi, R.A., Barrientos, G. & Cassiodoro, G.E. (2000-2002). Condiciones previas a la extinción de las poblaciones humanas del sur de Patagonia: una discusión a partir del análisis del registro arqueológico de la cuenca del lago Salitroso. *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano,* 19: 249-266.

Guichon, R., Muñoz, A.S. & Borrero, L.A. (2000). Datos para una tafonomía de restos óseos humanos en Bahía San Sebastián, Tierra del Fuego. *Relaciones de la Sociedad Argentina de Antropología,* 25: 297-311.

Gutiérrez, M.A., Kaufmann, C., González, M., Massigoge, A. & Álvarez M.C. (2010). Intrataxonomic variability in metopodial and femur bone density related to age in guanaco (*Lama guanicoe*). Zooarchaeological and taphonomical implications. *Journal of Archaeological Science,* 37 (12): 2226-3238.

Hajduk, A.J. & Lezcano, M.J. (2005). Un "nuevo viejo" integrante del elenco de instrumentos óseos de Patagonia: Los machacadores óseos. *Magallania,* 33 (1): 63-80.

Ioannidou, E. (2003). Taphonomy of animal bone: species sex age, and breed variability of sheep, cattle and pig bone density. *Journal Archaeological Science,* 30 (3): 355-365.

Johnson, E. (1985). Current Developments in Bone Technology. In (Schiffer, M.B., ed.) *Advances in Archaeological Method and Theory* 8. New York: Academic Press, pp.157-235.

Johnson, E. (1989). Human-modified Bones from Early Southern Plains Sites. In (Bonnichsen, R. & Sorg, M., eds.) *Bone Modification.* Orono: University of Maine Centre for the Study of the First Americans, pp.431-471.

Koon, H.E.C., Nicholson, R.A. & Collins, M.J. (2003). A practical approach to the identification of low temperature heated bone using TEM. *Journal of Archaeological Science,* 30: 1393-1399.

Kreutzer, L.A. (1992). Bison and deer bone mineral densities: comparisons and implications for the interpretation of archaeological faunas. *Journal Archaeological Science*, 19 (3): 271-294.

Lam, Y.M., Chen, X., Marean, C.W. & Frey, C.J. (1998). Bone density and long bone representation in archaeological faunas: comparing result from CT and Photon densitometry. *Journal Archaeological Science,* 25 (6): 559-570.

Lam, Y.M., Chen, X. & Pearson, O.M. (1999). Intertaxonomic variability in patterns of bone density and differential representation of bovid, cervid and equid elements in the archaeological record. *American Antiquity,* 64 (2): 343-362.

Lam, Y.M. & Pearson, O.M. (2004). Bone density studies and the interpretation of the faunal record. *Journal of Taphonomy,* 2 (2): 99-116.

Lyman, R.L. (1994). *Vertebrate Taphonomy*. Cambridge University Press, Cambridge.

Marean, C.W. (1995). Of taphonomy and zooarchaeology. *Evolutionary Anthropology,* 4 (2): 64-72.

Marean C.W. (1998). A critique of the evidence for scavenging by Neanderthals and early modern humans: new data from Kobeh Cave (Zagros Mountains) and Die Kelders (South Africa Middle Stone Age). *Journal of Human Evolution,* 35 (2): 111-136.

Marean, C.W. & Assefa, Z. (1999). Zooarchaeological evidence for the faunal exploitation behavior of Neandertals and early modern humans. *Evolutionary Anthropology,* 8 (1): 22-37.

Marean, C.W. & Cleghorn, N. (2003). Large mammal skeletal element transport: applying foraging theory in a complex taphonomic system. *Journal of Taphonomy,* 1: 15-42.

Marean, C.W. & Cleghorn N. (2004). The Destruction of Skeletal Elements by Carnivores: the Growth of a General Model for Skeletal Element Destruction and Survival in Zooarchaeological Assemblages. In (Pickering, T., Shick, K. & Toth, N., eds.) *Breathing Life into Fossils: Taphonomic Studies in Honor of C.K. (Bob) Brain*. Stone Age Institute Press: Stone Age Institute Publication Series. Number 2, pp. 37-66.

Marean, C.W. & Kim, S.Y. (1998). Mousterian large mammal remains from Kobeh Cave: behavioral implications for Neanderthals and early modern humans. *Current Anthropology* (Supplement), 39: 79-113.

Martín. F.M. (1998). Madrigueras, dormideros y letrinas: ap,oximación a la tafonomía de zorros. In (Borrero, L.A., ed.) *Arqueología de la Patagonia Meridional [Proyecto "Magallania]*. Concepción del Uruguay: Ediciones Búsqueda de Ayllu, pp.73-96.

Martín, F.M. (2006). *Carnívoros y huesos humanos de Fuego-Patagonia: aportes desde la tafonomía forense*. Sociedad Argentina de Antropología, Buenos Aires.

Massigoge, A., González, M., Kaufmann, C. & Gutiérrez, M.A. (2010). Observaciones actualísticas sobre meteorización ósea en restos esqueletales de guanaco. In (Berón, M., Luna, L., Bonomo, M., Montalvo, C., Aranda, C. & Carrera Aizpitarte, M., eds.) *Mamül Mapu: pasado y presente desde la arqueología pampeana*. Ayacucho: Editorial Libros del Espinillo, pp. 309-322.

Mazzoni, E. & Vázquez, M. (2000). La provincia de Santa Cruz: una visión general. *El Gran Libro de Santa Cruz*. Editorial Alfa Centro Literario, Milenio Ediciones.

Mengoni Goñalons, G.L. (1999). *Cazadores de guanacos de la estepa patagónica.* Sociedad Argentina de Antropología, Buenos Aires.

Miotti, L.L. (1998). *Zooarqueología de la meseta central y costa de Santa Cruz. Un enfoque de las estrategias adaptativas aborígenes y los paleoambientes.* Museo de Historia Natural. Secretaria de Gobierno, Departamento de San Rafael, Mendoza.

Miotti, L.L. (1990-1992). La experimentación simulativa de fracturas y marcas óseas y sus implicancias arqueológicas. *Arqueología Contemporánea,* 3: 39-64.

Mondini, M. & Muñoz, A.S. (2008). Puma as taphonomic agents: A comparative analysis of actualistic studies in the Neotropics. *Quaternary International,* 180 (1): 52-62.

Montes, C., De Lamo, D.A. & Zavatti, J. (2000). Distribución de abundancias de guanaco (*Lama guanicoe)* en los distintos ambientes de Tierra del Fuego, Argentina. *Mastozoología Neotropical,* 7 (1): 5-14.

Muñoz, A.S. & Belardi, J.B. (1998). El marcado perimetral en los huesos largos de guanaco de Cañadón Leona (Colección Junius Bird): implicaciones arqueofaunísticas para Patagonia Meridional. *Anales del Instituto de la Patagonia, Serie Ciencias Sociales,* 26: 107-118.

Oporto, N.R. (1983). Contribución al conocimiento sobre el comportamiento de guanaco y posibles aplicaciones. Argentina. *Mundo Ameghiniano,* 4: 1-19.

Outram, A.K. (2001). A new approach to identifying bone marrow and grease exploitation: Why the "indeterminate" fragments should not be ignored. *Journal of Archaeological Science,* 28 (4): 401-410.

Pasda, K. (2005). Some taphonomic investigations on reindeer (*Rangifer tarandus groenlandicus*) in West Greenland. In (O´Connor, T., ed.) *Biosphere to Litosphere. New Studies in Vertebrate Taphonomy*. Oxford: Oxbow Books, pp. 4-15.

Pickering, T.R., Marean, C.W. & Domínguez-Rodrigo, M. (2003). Importance of limb bone shaft fragments in Zooarchaeology: a response to "On *in situ* attrition and vertebrate body part profiles" (2002), by M.C. Stiner. *Journal of Archaeological Science,* 30 (11): 1469-1482.

Pierce, M.C., Bertocci, G.E., Vogeley E. & Moreland M.S. (2004). Evaluating long bone fractures in children: a biomechanical approach with illustrative cases. *Child Abuse & Neglect,* 28 (5): 505-524.

Puig, S. & Videla, F. (1995). Comportamiento y organización social del guanaco. In (Puig, S., ed.) *Técnicas para el manejo del Guanaco*. Gland: UICN, pp.97-118

Raedeke, K.J. (1978). *El guanaco de Magallanes, Chile. Distribución y Biología*. Ministerio de Agricultura. Publicación Técnica N° 4, Corporación Nacional Forestal de Chile.

Rindel, D.D. (2009). *Arqueología de momentos tardíos en el noroeste de la Provincia de Santa Cruz (Argentina): una perspectiva faunística*. Unpub PhD, Facultad de Filosofía y Letras, Universidad de Buenos Aires.

Rindel, D.D., Cassiodoro, G. & Aragone, A. (2007). La utilización de mesetas altas durante el Holoceno tardío: el sitio Cerro Pampa 2 Ojo de Agua (Santa Cruz, Argentina). In (Morello, F., Martinic, M., Prieto, A. & Bahamonde, G., eds.) *Arqueología de Fuego-Patagonia. Levantando Piedras, Desenterrando Huesos… y Develando Arcanos.* Punta Arenas: Ediciones CEQUA, pp.649-661.

Savanti, F., Bourlot, T. & Aragone, A. (2005). Zooarqueología y uso del espacio en Lago Cardiel, Provincia de Santa Cruz, Patagonia Argentina. *Archaeofauna. International Journal of Archaeozoology,* 14: 111-127.

Shipman, P. (1981). Applications of Scanning Electron Microscopy to Taphonomic Problems. In (Cantwell, A.M.E., Griffin, J.B. & Rothschild, N.A., eds.) *The Research Potential of Anthropological Museums Collections* 376. New York: New York Academy of Sciences, pp. 357-385.

Silva, S.I., Jaksic, F.M. & Bozinovic, F. (2005). Nutritional ecology and digestive response to dietary shift in the large South American fox, *Pseudalopex culpaeus. Revista Chilena de Historia Natural,* 78 (2): 239-246.

Stahl, P.W. (1999). Structural density of domesticated South American Camelid skeletal element and the archaeological investigation of prehistoric Andean ch´arki. *Journal of Archaeological Science,* 26 (11): 1347-1368.

Stiner, M.C. (1998). Comment on Marean & Kim "Mousterian large mammal remains from Kobeh Cave: behavioral implications for Neanderthals and early modern humans". *Current Anthropology* (Supplement), 39: 98-103.

Stiner, M.C. (2005). *The faunas of Hayonim Cave, Israel. A 200.000-year record of Paleolithic diet, demography, and society*. American School of Prehistoric Research.

Bulletin 48. Peabody Museum of Archaeology and ethnology, Harvard University, Cambridge, Massachusetts.

Sturzenbaum, P. & Borreli, P. (2001). Manejo de riesgos climáticos. In (Borreli, P. & Oliva, G., eds.) *Ganadería Ovina Sustentable en la Patagonia Austral*. *Tecnologías de Manejo Extensivo*. Buenos Aires: INTA-Santa Cruz, Editorial ErreGé & Asociados, pp.255-270.

Tappen, N.C. (1969). The relationship of weathering cracks to split-line orientation in bone. *American Journal of Physical Anthropology,* 31 (2): 191-198.

Tappen, N.C. & Peske, G.R. (1970). Microscopic examination of human femurs buried at Washington Island, Wisconsin. *American Antiquity,* 35 (4): 463-465.

Yravedra, J. & Domínguez-Rodrigo, M. (2009). The shaft-based methodological approach to the quantification of long limb bones and its relevance to understanding hominid subsistence in the Pleistocene: application to four Paleolithic sites. *Journal of Quaternary Science,* 24 (1): 85-96.

Zapata, S., Travaini, A., Delibes, M. & Martínez-Peck, R. (2005). Food habits and resource partitioning between gray and culpeo foxes in southeastern Argentine Patagonia. *Studies in Neotropical Fauna and Environment,* 40 (2): 97-103.