Taphonomy and zooarchaeology in the Neotropics: A view from northwestern Patagonian forest and steppe

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Abstract

Modes of faunal exploitation in NW Chubut Province (Patagonia, Argentina) during the last 3500 calibrated years BP are discussed, based on taphonomic and zooarchaeological analyses. Bone assemblages were recovered from archaeological sites of the Sub-Antarctic forests and the extra-Andean Patagonian steppe, where huemul (Hippocamelus bisulcus) and guanaco (Lama guanicoe) were, respectively, the main staple. In the steppe, lesser rhea (Pterocnemia pennata), a medium-sized flightless bird, also was integrated into the hunter-gatherer diet. Rodents, carnivores, flying birds, and fishes also were recovered. Different processes and agents were involved in the accumulation of small vertebrates bone assemblages (e.g. birds of prey, foxes, and small carnivores). In the steppe, only two taxa of small vertebrates—birds and mountain viscacha (Lagidium viscacia)—can be related with human subsistence activities. These two taxa and all large vertebrates reveal fat-oriented carcass processing.

Guanaco bone assemblages associated both with ceramic and non-ceramic technologies do not show changes in carcass processing. Moreover, the similarities in bone grease exploitation suggest boiling prior to the appearance of pottery.

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1. Introduction

The mode of exploitation of a particular faunal resource comprises decisions related to its acquisition, processing and consumption, made based on the intended products (sensu Mengoni Goñalons, 1999). These modes are influenced by factors such as the environment, resources, available technologies, and social and ideological aspects (Kelly, 1995; Binford, 2001; Politis and Saunders, 2002). From this perspective, some characteristics of the Neotropical region, such as the low diversity of wild ungulates (Franklin, 1982) or the relatively low levels of mammal carnivore competition (Mondini, 2003), suggest particular humans–animals interactions, different from those expected in other regions of the world. Furthermore, these particularities encourage the use and development of specific taphonomic models considering the environmental conditions of this biogeographical region (Cruz, 2003; Mondini, 2003).

The goal of this paper is to characterize animal prey in Sub-Antarctic forests and steppe environments from northwestern Patagonia during the last 3500 years. This is the first archaeofaunal and taphonomic study concerning this area, and it is also the first that compares the prehistoric hunter-gatherers modes of faunal exploitation in those contiguous environments. The inferred modes of exploitation are examined considering local factors, such as the rain shadow effect and its relationship with environmental productivity and animal biomass, temporal and spatial distributions of potential prey species, the low availability of other energy sources (carbohydrates) beyond animal fat and the impact of ceramic availability on carcass processing (Fernández, 2006). Neotropical conditions were taken into account to propose models of faunal exploitation.

2. Study area

In northwest Chubut Province, Sub-Antarctic forests and steppe environments reflect the rainfall gradient, which decreases from west to east. The Andes, in combination with the prevailing westerly winds, produces a rain shadow

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effect. In Patagonian forested environments, the annual rainfall is around 2500 mm to 700 mm, descending to 150 mm in the eastern steppe (Marchetti and Prudkin, 1982). In this study area, Sub-Antarctic forests spread over the Futaleufú Basin, which ranges from 42°30′ to 43°S, and from the Argentinean–Chilean border to the meridian 71°30′W (Fig. 1).

This is a glacially modified landscape with deep lakes, valleys and moraine chains that ranges between 1700 and 550 m above sea level. On slopes and riverbanks, mixed forests of deciduous *Nothofagus* with grassland patches predominate. On the lower and wetter zones and around lakes, there are "mallines" (wetlands composed of dense Gramineae grasslands). Toward the eastern forest-steppe ecotone, *Austrocedrus chilensis* forests are important. Mean annual temperature ranges from 4 to 8 °C (Bernades, 1981; Marchetti and Prudkin, 1982). Although Sub-Antarctic forests offer numerous edible plants (Rapoport et al., 2003), these are mainly low energy value roots and fruits, and the forests do not provide the more nutritious nuts.

The steppe is represented by Piedra Parada area (42°20′–43°S and 69°30′–70°30′W, Fig. 1) is located on the steppe. The principal landform in this area is the drainage system of the Chubut River. The steppe has extremely arid conditions (138 mm mean annual precipitation) and shrub steppe vegetation. Temperature ranges between 17 °C in January to 3 °C in July (Aschero et al., 1983). In the Piedra Parada area some edible plant remains (*Schinus* sp., *Berberis* sp., *Bromus unioloides*, *Tropaeolum* sp. and *Arjona tuberosa*) were recovered from archaeological sites (Nacuzzi and Pérez de Micou, 1983–1985; Pérez de Micou, 1988), but these plants would provide low amounts of energy.

Ungulate abundance is directly indicated by the percentage of biomass represented by leafy plant material. In the forest, ungulate abundance is lower than in the steppe where most of the biomass is represented by reproductive tissue (Binford, 2001). Sub-Antarctic forests are the habitat

of two cervids, huemul (*Hippocamelus bisulcus*) and pudú (*Pudu puda*). The former lives in small family groups, up to four individuals, and weighs 90–100 kg. This species shows seasonal movements varying in altitude range between winter (500–800 masl) and summer (1000–1400 masl, Povilitis, 1978, 1983; Serret, 2001). Pudú is one of the smallest cervids in Patagonia (10–12 kg), and like huemul also has solitary habits (Ramilo, 2001). Guanaco (*Lama guanicoe*), the largest terrestrial vertebrate of Argentina (100–120 kg) lives in the steppe. It social structure is formed by family groups (7–16 individuals), male groups (20–50 individuals), and solitary males (Franklin, 1982). Lesser rhea or choique (*Pterocnemia pennata*), a medium-sized (25 kg) flightless bird (Daciuk, 1978), also lives in the steppe.

Other potential prey in both Sub-Antarctic forest and steppe are mountain viscacha (*Lagidium viscacia*), one of the larger rodents of Patagonia (2–2.5 kg), armadillos (only in the steppe, *Zaedyus pichiy*, *Chaetophractus villosus*), foxes (*Lycalopex*), birds (especially anatids), and fishes (Galaxiidae, only in the Sub-Antarctic forest; and perch, *Percichthys*, Cabrera and Willink, 1973; Ortubay et al., 1994).

3. Materials and methods

Bone assemblages come from six rock shelters, two from the Sub-Antarctic forest and four from the steppe. Rock art style, lithic raw materials and vegetation remains suggest relationships between both environments (Pérez de Micou, 2002; Bellelli et al., 2006). Alero del Sendero de Interpretación (unit ASI site) and Cerro Pintado (units CP site Sup and CP site Exc) are located in Sub-Antarctic forest and dated between 300 and 2000 calibrated years BP (Table 1). Campo Cerda 1 (units CCe1 sites 2–3 and CCe1 site 5), Piedra Parada 1 (unit PP1 site), Campo Moncada 2 (units CM2 sites 0–2b and CM2 site 2c) and Campo Nassif 1 (unit CN1 site) are located in the steppe. Site chronology
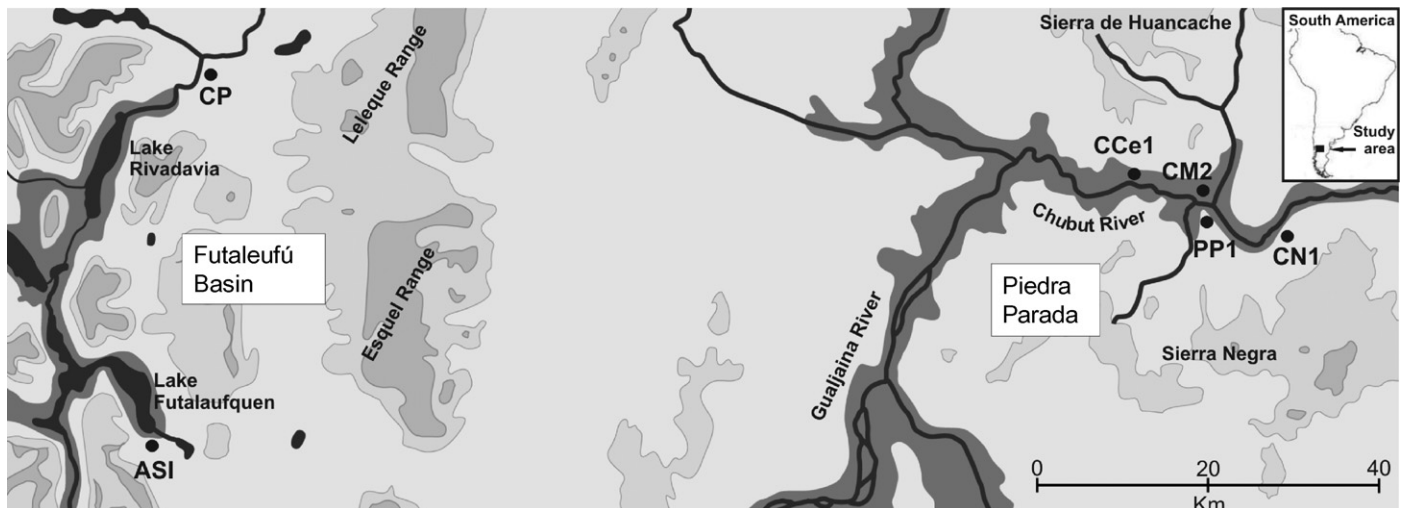

Fig. 1. Map in the study area in NW Chubut (Patagonia, Argentina).

Table 1
Chronology and bone processing technology associated to bone assemblages

Environment	Site	Zooarchaeological units	Chronology (years calibrated BP)	Technology associated
Sub-Antarctic forest	Alero del Sendero de Interpretación (ASI)	ASI	310–510 to 1340–1730	Pottery
	Cerro Pintado (CP)	CP Sup	–	Pottery
		CP Exc	544–703 to 1575–1982	Pottery
Steppe	Campo Cerda 1 (CCe1)	CCe1 2–3	510–660	Pottery
		CCe1 5	1350–1696 to 2790–3170	Fiber based artifacts
	Piedra Parada 1 (PP1)	PP1	1140–1350	Pottery
	Campo Moncada 2 (CM2)	CM2 0–2b	560–920 to 660–930	Pottery
		CM2 2c	1510–1880 to 3340–3560	Fiber-based artifacts
	Campo Nassif 1 (CN1)	CN1	310–650	Pottery

spans the last 3500 BP (calibrated). Seven units have bone assemblages associated with pot sherds (Table 1).

General taphonomic process (Lyman, 1994) and regional accumulation and preservation characteristics (Borrero and Muñoz, 1999; Borrero, 2001; Savanti, 2002; Cruz, 2003) were considered. Laboratory procedures included anatomical and taxonomical identification and the examination of bone modifications. Specimens were initially examined with the naked eye, followed by inspection under $10\times$ hand lens. To resolve questions about particular specimens, a binocular zoom microscope, with magnification up to $16\times$, was used. The abundance of different taxa was quantified using the number of identified specimens (NISP) and the minimum number of individuals (MNI). The MNI count distinguishes the side for paired bones and takes into account the fusion stage. Based on body size, two groups were defined: small vertebrates (SV, <10–15 kg body weight) and large vertebrates (LV, >15 kg). The general category Large Size Vertebrate includes Large Mammalia specimens and lesser rhea fragmented leg bones. Although Rodentia specimens were not analysed in detail, some taphonomic processes related to their accumulation were inferred. Measures of anatomical abundance were based on MNE counts for bone. In this study, the MNE count considered shaft fragments, right and left sides in limb bones, innominate and mandible and also unique bone landmarks (Mengoni Goñalons, 1999). MAU and %MAU were also calculated (Binford, 1984).

To explore bias towards a particular anatomical region, standardized MNE (Stiner, 1991, 1994) was used. Based on the nutritional value of each skeletal part (De Nigris, 2004), eight anatomical regions were established: (1) head (skull, mandible and hyoids; (2) column (cervical vertebrae, thoracic, lumbar and sacrum); (3) rib (ribs and sternum); (4) girdles (innominate and scapula); (5) upper leg (humerus and femur); (6) middle leg (radioulna and tibia); (7) lower leg (metacarpal and metatarsal), and (8) calcaneum and feet (calcaneum and first and second phalanx).

The rank correlation coefficient between %MAU and structural bone density (SBD) values was used to explore differential preservation in guanaco (Stahl, 1999) and choique (Cruz and Elkin, 2003) bone assemblages. In the cases of huemul and mountain viscacha, due to the lack of specific studies, white tailed deer (*Odocoileus virginianus*) and domestic rabbit (*Oryctolagus cuniculus*) values were employed (Lyman, 1994; Pavao and Stahl, 1999). Other frames of reference utilized to examine skeletal part profiles were guanaco (Borrero, 1990b, modified by Lyman, 1992), huemul (Belardi and Gómez Otero, 1998) and choique (Giardina, 2004) utility indexes (MUI); guanaco (Mengoni Goñalons, 1996) and huemul (Belardi and Gómez Otero, 1998) marrow indexes (MI), and guanaco drying utility index (DUI, De Nigris and Mengoni Goñalons, 2004).

The representation of long bone ends and vertebrae (bone grease-rich elements) were used to assess the effect of ceramic technology on carcass processing in guanaco assemblages from the Piedra Parada area. Epiphysis representation was detailed by end/shaft ratio (MNE proximal end + MNE distal end/MNE shaft = 2). Possible representation biases were explored through the correlation between %MAU of long bone end and (a) SBD and (b) epiphyses grease content. For the latter, because this value has not been calculated for guanaco, *Bison bison* values (Brink, 1997) were used, because there are consistent patterns in the distribution of bone grease "at least in leg bones of large ungulates" (Brink, 1997, p. 270). Besides, this measure has not been calculated for guanaco. Centrum or body—the greasiest part of the vertebrae—contribution to MNE of each vertebra was estimated using the formula MNE centrum × 100/MNE complete vertebrae. Specimens were inspected for cut marks or percussion marks related to exposition of cancellous bone. The size of bone fragments was considered to identify any pot-sizing effect (Yellen, 1977; Binford, 1978; Lupo and Schmitt, 1997).

4. Results

4.1. Small vertebrate

In the Futaleufú Basin, SV bone assemblages are composed of birds and mammals, especially rodents

(Rodentia, *Lepus* sp. (introduced hare), and mountain viscacha). Except for the Rodentia assemblage from the CP site, SV bones are rare. It was almost impossible to relate SV bones to specific taphonomic process. In the case of *Lepus* sp., elements represented, the spatial arrangement and the distribution of gnawing damages on bones are similar to modern bone assemblages transported by foxes (*Lycalopex* sp., personal observation). Rodent galleries, some with rodent bones inside, indicate that the CP site Rodentia bone assemblage was partially related to rock shelter use as rodent habitat. No specimens of SV retrieved in forest sites have evidence of carcass processing.

In the Piedra Parada area, Rodentia taxonomically dominates among SV. Mountain viscacha, armadillos, birds and fishes are also present in all sites. The remaining taxa are limited in the samples (Table 2). In this area, SV indicated occupational alternation between animal predators and human beings. Several variables: prey behaviour, presence of pellets, and bone modification characteristics, show that Strigiformes and/or Falconiformes accumulated most of the Rodentia and Didelphidae (southern opossum) specimens. Bone assemblages of mountain viscacha, armadillos and fishes were transported, gnawed in situ and/or accumulated by faeces decomposition. Foxes and, in lesser amounts, small carnivores such as felids, hog-nosed skunk, and Patagonian weasel could be involved in these actions.

Almost all skeletal parts of mountain viscacha are represented. Although vertebrae and ribs are lacking in the assemblages, anatomical representation could not be related to mineral bone density (CM2 sites 0–2b $r_s = 0.52$, $P > 0.05$; CN1 site $r_s = 0.47$, $P > 0.05$). A few specimens show cut and percussion marks (PP1 site, 10%; CM2 0–2b, 1.3%; and CN1 site, 4.2%) and locations reflect disarticulation and defleshing. Longitudinal fracture patterns on femurs and tibias suggest bone breakage for marrow extraction.

Table 2
Bone assemblage composition for each zooarchaeological unit: number of identified specimens (NISP), and minimum number of individuals (MNI, between parentheses)

Taxon	Sub-Antarctic forest			Steppe					
	ASI	CP Sup	CP Exc	CCe1 2-3	CCe1 5	PP1	CM2 0–2b	CM2 2c	CN1
Small vertebrates									
Mammalia (small size)	0 (0)	2 (1)	1 (1)	2 (1)	9 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Rodentia (rodents)	3[a]	7[a]	737[a]	2745[a]	2469[a]	329[a]	1757[a]	2107[a]	263[a]
Lepus sp. (hare)	2 (2)	8 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lagidium viscacia (mountain viscacha)	0 (0)	0 (0)	3 (1)	10 (1)	14 (2)	10 (1)	77 (3)	13 (1)	48 (3)
Myocastor coypus (coypu)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (2)	0 (0)	0 (0)	2 (1)
Canidae	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Lycalopex sp.(fox)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)
Felidae	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
Conepatus sp. (hog-nosed skunk)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lyncodon patagonicus (Patagonian weasel)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Fam. Didelphidae (southern opossum)	0 (0)	0 (0)	0 (0)	16 (6)	14 (5)	0 (0)	1 (1)	2 (2)	0 (0)
Fam. Dasipodidae (armadillos)	2 (1)	0 (0)	1 (1)	10 (2)	7 (1)	1 (1)	11 (1)	1 (1)	12 (1)
Fishes	0 (0)	0 (0)	0 (0)	9 (1)	19 (1)	0 (0)	2 (1)	0 (0)	0 (0)
Siluriforme	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Percichthys sp. (perch)	0 (0)	0 (0)	0 (0)	22 (4)	42 (4)	1 (1)	2 (1)	3 (1)	0 (0)
Fam. Tropiduridae (neotropical ground lizards)	0 (0)	0 (0)	0 (0)	3 (1)	4 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Aves	0 (0)	0 (0)	0 (0)	3 (1)	5 (1)	1 (1)	2 (2)	4 (1)	6 (2)
Passeriformes	0 (0)	0 (0)	5 (1)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Large vertebrates									
Mammalia (large size)	0 (0)	69 (–)	239 (–)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Artiodactyla	25 (–)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Ovis sp.(domestic sheep)	43 (3)	27 (2)	8 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Equus sp. (horse)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Bos taurus (domestic cow)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hippocamelus bisulcus (huemul)	5 (1)	3 (1)	108 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lama guanicoe (guanaco)	0 (0)	0 (0)	16 (1)	242 (4)	305 (4)	273 (6)	167 (2)	83 (3)	119 (3)
Pterocnemia pennata (choique)	0 (0)	0 (0)	0 (0)	42 (2)	9 (2)	5 (1)	8 (1)	7 (1)	7 (1)
Large size vertebrate	0 (0)	0 (0)	0 (0)	195 (–)	282 (–)	409 (–)	407 (–)	158 (–)	140 (–)
Total NISP	80	117	1119	3302	3183	1034	2435	2378	598
Indeterminate	538	307	5831	313	444	378	1194	321	292
NR[b]	618	424	6950	3615	3627	1412	3629	2699	890

[a]MNI not calculated.
[b]NR: total bone recovered (identified + indeterminate).

Perch (*Percichthys* sp.) are represented by head bones and caudal vertebrae. Less diagnostic elements such as radials, spines and vertebrae, also probably belong to perch. The prevalence of cranial bones is compatible with a human discard context (Butler, 1993; Stewart and Gifford-González, 1994) even though this pattern has been spotted for fish carcasses transported and consumed by foxes (Zangrando, 2003). Taking into account carnivore damage and digestion evidence, and hair and other organic residues stuck on some fish bones, the last interpretation is the most probable.

Half of the Aves specimens shows bone modifications related to human consumption (percussion marks) and to use as raw material (one specimen could be interpreted as the residue of an instrument manufacture process). Exploitation is difficult to infer from the only specimen of Canidae presenting cutmarks.
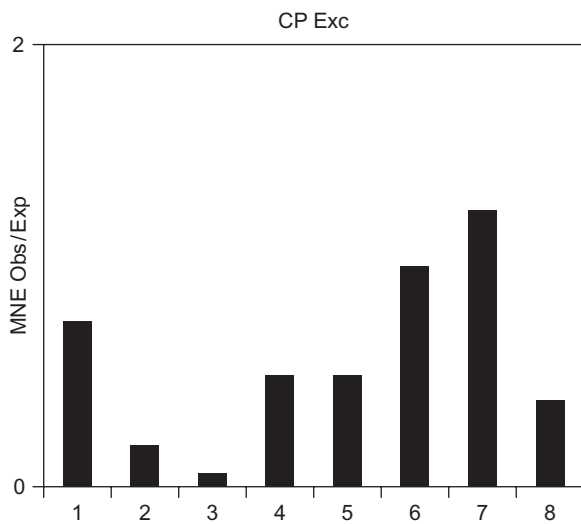

Fig. 2. Anatomical representation pattern (standardized MNE) for huemul in unit CP Exc: (1) head; (2) column; (3) rib; (4) girdles; (5) upper leg; (6) middle leg; (7) lower leg; and (8) calcaneum and feet.

4.2. Large vertebrates

4.2.1. Taxonomy diversity and taphonomy

In the Futaleufú Basin, LV bone assemblages are composed of native (huemul, guanaco) and introduced species (*Ovis* sp.; *Bos taurus*; *Equus* sp.). The last three show the importance of modern bone deposition. Even more relevant, diagenetic processes (ASI site) and trampling-related bone breakage (CP site) diversely affected the integrity of bone assemblages and the possibility of inferring human conduct.

In the Piedra Parada area, Large Size Vertebrates specimens are the most numerous, except at CCe1. In PP1, the lower degree of identifiability may be related to a higher incidence of weathering. In unit 0–2b at the CM2 site, it is related to slightly more intense carnivore scavenging. All sites contain choique bones, although with a very low NISP.

Little evidence of carnivore action was identified, suggesting scavenging of bone assemblages left by humans. Due to the low destructive power of Patagonian carnivores, scavenging did not influence the conformation of skeletal part profiles.

4.2.2. Anatomical abundance

Huemul (unit CP site Exc) presents a skeletal parts profile in which middle and lower leg anatomical regions are most common (radioulna and tibia, and metapodials, respectively), followed by the head (Fig. 2). The former mainly provide marrow in moderate or low amounts, while the latter have organs rich in fat. Anatomical regions that only provide meat (Column, Ribs, and Girdles) are practically absent.

Although there is a positive and statistically significant correlation between %MAU and SBD values, the relationship between both variables is very feeble (Table 3). A lack of association was also seen between the skeletal parts representation and the MUI, or the MI (Table 3).

In the steppe, the prevalence of bones providing little marrow (lower leg) or little meat and a moderate amount of

Table 3
Coefficients correlations (Spearman's rank and Pearson's) between skeletal parts abundance and structural density, and skeletal parts abundance and utility indexes

Taxon	Unit	%MAU vs. SBD[a]	%MAU vs. MUI[b]	%MAU vs. MI[c]	%MAU vs. DUI[d]
Huemul	CP Exc	$r_s = 0.34$ $P<0.05$*	$r = -0.34$ $P>0.05$	$r_s = -0.13$ $P>0.05$	–
Guanaco	CCe1 2–3	$r_s = 0.35$ $P<0.05$*	$r = -0.33$ $P>0.05$	$r_s = -0.23$ $P>0.05$	$r = -0.54$ $P<0.05$
	CCe1 5	$r_s = 0.29$ $P>0.05$	$r = -0.19$ $P>0.05$	$r_s = 0.64$ $P>0.05$	$r = -0.62$ $P<0.05$
	PP1	$r_s = 0.15$ $P>0.05$	$r = 0.27$ $P>0.05$	$r_s = 0.14$ $P>0.05$	$r = -0.56$ $P<0.05$
	CM2 0–2b	$r_s = 0.21$ $P>0.05$	$r = -0.25$ $P>0.05$	$r_s = 0.21$ $P>0.05$	$r = -0.61$ $P<0.05$
	CM2 2c	$r_s = 0.10$ $P>0.05$	$r = -0.16$ $P >0.05$	$r_s = 0.28$ $P>0.05$	$r = -0.57$ $P<0.05$
	CN1	$r_s = 0.11$ $P>0.05$	$r = -0.08$ $P>0.05$	$r_s = 0.33$ $P>0.05$	$r = -0.49$ $P<0.05$
Ñandú	CCe1 2-3	$r_s = 0.41$ $P<0.05$*	$r = 0.24$ $P>0.05$	–	–

*Statistically significant.
[a] Structural bone density.
[b] Meat utility index.
[c] Marrow index.
[d] Guanaco drying utility index.

marrow (middle leg) characterizes guanaco skeletal parts profiles. The variability observed in appendicular skeleton representations could be associated with smaller variations due to processing. In contrast, the axial skeleton exhibits an uniform representation in all guanaco assemblages (Fig. 3). Meat utility indices (MUI, MI) and SBD did not condition the anatomical representation. In the case of unit 2–3, site CCe1, the correlation is positive and statistically significant, although the relationship is weak. However, skeletal parts profiles show negative and statistically significant relationships with DUI (Table 3), indicating the transport of axial elements to other loci for deferred consumption. The lack of relationship between skeletal parts representation and most ethnoarchaeological and experimental frames of reference suggests that these bone assemblages came from final consumption localities (Mengoni Goñalons, 1999).

The prevalence of shafts above epiphyses, mainly in the elements with a higher rate of intra-bone nutrients, is also characteristic of guanaco appendicular specimens (Table 4). The low destructive power of Patagonian scavengers and the low frequencies of specimens with carnivore marks indicate that epiphysis attrition by

Table 4
Long bone epiphysis: shaft ratio for Piedra Parada guanaco assemblages

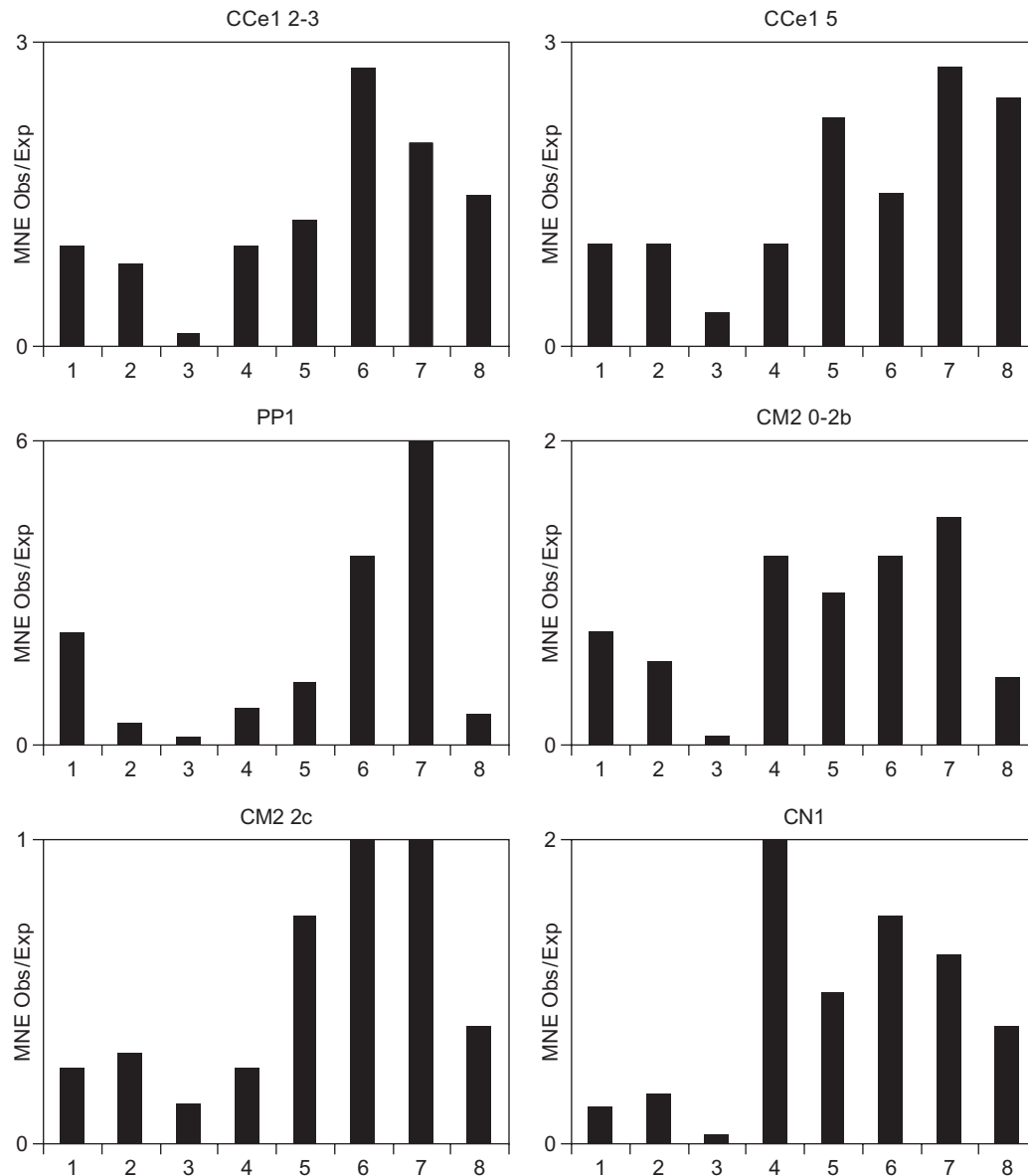|	CCe1 2–3	CCe 5	PP1	CM2 0–2b	CM2 2c	CN1
Humerus	0.25	0.40	1.50	0.67	0.00	0.33
Radioulna	1.25	0.00	2..25	0.50	0.33	4.00
Femur	0.00	0.25	0.33	0.00	1.00	1.00
Tibia	0.40	0.25	0.56	0.00	0.00	0.33
Metapodial	1.20	0.92	0.54	1.33	0.60	4.00

Fig. 3. Anatomical representation patterns (standardized MNE) for guanaco in steppe sites: (1) head; (2) column; (3) rib; (4) girdles; (5) upper leg; (6) middle leg; (7) lower leg; and (8) calcaneum and feet.

carnivores can be rejected. In the CCe1 sites 2–3, CCe1 site 5, and CN1 site bone assemblages, the observed disproportion between end and shafts as well as their relative frequency per anatomical unit may be associated with their mineral density (Table 5). However, the negative correlation between guanaco epiphyses and grease content indicates that human processing underlies the patterns observed in units CCe1 sites 2–3, CCe1 site 5, and CM2 site 2c (Table 5).

On the other hand, vertebrae bodies are scarcely represented, particularly as regards cervical and lumbar vertebrae (Fig. 4). In this case, this pattern could not be attributed to carnivore action. Most probably, the relative absence of centrum may be associated with the processing of vertebrae parts richer in bone grease (e.g. White, 1992).

Choique is almost exclusively represented by hind legs, especially the distal section (tibiatarsal, tarsal-metatarsal and phalanxes, Fig. 5). Thick-wall bones form hind legs with a central canal filled with marrow, a characteristic associated with these birds' running adaptation. Although correlation between %MAU and SBD is positive and statistically significant (Table 3), the result might be affected by the low element representation diversity. Correlation was only calculated for unit CCe1 sites 2–3

Table 5
Coefficients correlations (Spearman's rank) between guanaco long bone ends abundance (%MAU LBE) and structural bone density (SBD), and fat content (GW) in leg bones of *Bison bison*

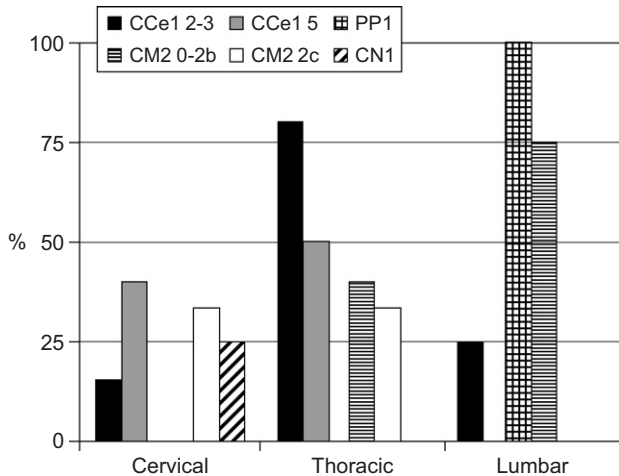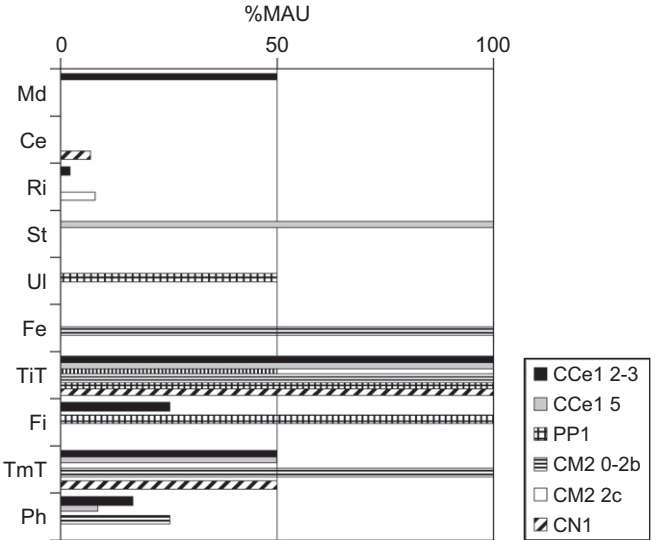| Unit	%MAU LBE vs. SBD	%MAU LBE vs. GW
CCe1 2–3	0.81 <0.05*	−0.81 <0.01*
CCe1 5	0.64 <0.05*	−0.75 <0.05*
PP1	0.53 >0.05	−0.38 >0.05
CM2 0–2b	0.05 >0.05	−0.20 >0.05
CM2 2c	0.40 >0.05	−0.62 <0.05*
CN1	0.73 <0.05*	−0.57 >0.05

*Statistically significant.

Fig. 5. Anatomical representation pattern (%MAU) for choique in steppe sites (Md: mandible; Ce: cervical vertebrae; Ri: ribs; St: sternum; Ul: ulna; Fe: femur; TiT: tibiatarsal; Fi: fibulae; TmT: tarsal-metatarsal; Ph: phalanges).

because the other units have small sample sizes. Even for the CCe1 2–3 sites choique assemblage, with the highest NISP and the greatest diversity of parts, only 9 out of 33 values correlated with mineral density have a figure other than zero. The same might be argued as regards the correlation between %MAU and MUI (Table 3).

4.2.3. Bone modifications related to carcass processing

Almost all LV taxa may be linked to prehistoric processing of animal prey. The exceptions are *Ovis* sp. and *Bos taurus* from CP site. Marks observed in these bone assemblages were made with metal knives and are related to the current human use of that shelter.

In the huemul assemblage (CP site Exc) the frequency of specimens with marks reaches 17% of NISP. In this case, cut marks are related to disarticulation, defleshing and preparation for cracking during marrow processing. Percussion marks reflect marrow extraction and are present in almost all marrow-bearing long bones (Table 5).

In guanaco bone assemblages, specimens with processing marks vary between 20% and 59% of NISP (Table 5). The observed differences between assemblages are mostly related to sample size. Consequently, the variation in the proportion of marked bones proportions is not related to an emphasis on processing guanaco carcasses. Generally, specimens with cut marks prevail, although some bone assemblages specimens with percussion marks are as frequent as or more frequent than those with cut marks (Table 5). Marks show all the processing stages of a carcass. All marrow-bearing bones were fragmented but those with a very low proportion of marrow (calcaneus, first and second phalanxes) received a more variable treatment. The consumption of all anatomical elements containing marrow was observed in only CCe1 site.

Fig. 4. Centrum contribution (%) to MNE of cervical, thoracic and lumbar vertebrae.

In choique bone assemblages, marks are located exclusively on the hind legs. Cut and percussion marks indicate the use of meat, marrow, and sinew.

Specimens with marks in Large Size Mammalia (15%), Artiodactyla (12%), and Large Size Vertebrate (35%) bone assemblages mainly show percussion signs (negative flakes scars, impact points, percussion grooves, and flake scars). It follows that the loss of identifiability may be partly related to human processing.

Although specific analyses (e.g. organic residue) are yet to be done, this study assumed that ceramic technology was used for faunal processing. However, bone assemblages lack any kind of modification related to the use of ceramic to process LV carcasses. There are neither cuts nor impacts aimed at the spongy tissue's exposure, nor standardization in the bones specimens' size suggesting a pot-sizing effect.

5. Discussion

5.1. Modes of faunal exploitation

5.1.1. Small vertebrates

In the steppe, flying birds have contributed in an insignificant way to subsistence: meat, marrow and bone raw material were utilized. Canidae bones might have also been used as raw material. The finding of a burin made out of a fox's radius (unit CCe1 site 5) and the use of fox skins to make coats in historical times (Prieto, 1997) support this possibility (Table 6).

Mountain viscacha was also another occasional and supplementary resource. Despite being one of the biggest Patagonian rodents, the difficulties in trying to catch it and the small number of individuals per colony might explain their poor contribution to the diet. Skeletal part profiles indicate that complete carcasses were transported to sites, and cut and percussion marks show the use of meat and marrow, even when the latter appears in negligible amounts. Both skeletal part profiles and the low frequency of specimens with marks are compatible with ethnoarchaeological and archaeological data linked to small prey procurement and consumption (Stahl, 1996; Quintana, 2005).

5.1.2. Huemul

In the forest, huemul was the main staple. MNI is consistent with huemul's low population density and the small size of its social groups. Although bone assemblages do not offer hints on the seasonality, ASI and CP sites are within the huemul's winter altitude range (500 masl). Based on this, winter might have been the hunting season because procurement and transport costs during summer must have been increased by the ascent up to 1000 m asl through a thickly vegetated landscape.

Hunting at the sites' surroundings is supported by skeletal parts profiles (Fig. 2) and those modifications associated with carcass processing. The huemul bone assemblage reflects the first steps in carcass reduction and the use of marrow from lower legs, a consumption that usually takes place in initial processing loci (Yellen, 1977; Binford, 1978). Additionally, consumption and discard of lower legs have the benefit of reducing transport costs. Nevertheless, spatial segmentation in huemul processing should not be interpreted in terms of selective transport. In this case, decisions about what to transport to other places

Table 6
Cut marks and percussion marks specimen frequencies (huemul, guanaco and choique)

Taxon	Unit	NISP	NISP M[a]	%NISP M	NISP Cm[b]	NISP Pm[c]	NISP CuPe[d]
Huemul	ASI	5	2	40	1	1	0
	CP Sup	3	1	33	1	0	0
	CP Exc	108	18	17	8	7	3
Guanaco	CP Exc	16	4	25	0	3	1
	CCe1 2–3	242	100	41	39	27	34
	CCe1 5	305	181	59	56	61	64
	PP1	273	54	20	37	10	7
	CM2 0–2b	167	65	39	40	12	13
	CM2 2c	83	31	37	12	14	5
	CN1	119	36	30	19	12	5
Choique	CCe1 2–3	42	28	67	7	14	7
	CCe1 5	9	4	44	1	1	2
	PP1	5	2	40	1	1	0
	CM2 0–2b	8	2	25	0	2	0
	CM2 2c	7	1	14	0	1	0
	CN1	7	6	86	4	0	2

[a]M: processing marks.
[b]Cm: cut marks.
[c]Pm: percussion marks.
[d]CuPe: cut and percussion marks in a single specimen.

do not imply abandoning skeletal parts but consuming them in one of the loci (e.g. Bartram, 1993).

5.1.3. Guanaco

Guanaco differs in importance in forest and steppe environments. In the former, guanaco is scarcely represented, and bone modifications mainly indicate the use of limb bone marrow. Conversely, in the steppe guanaco played a fundamental role in terms of subsistence. MNI (Table 2) and data on bone fusion suggest the exploitation of family groups, mainly animals older than 1 year. Skeletal parts profiles and processing marks indicate that there was no selective transport, and carcasses were entirely used. Ribs present different processing and consumption trajectories related to their deferred consumption. The great diversity of skeletal parts (Fig. 3); the high fragmentation ratio; the percentage of specimens with processing marks (Table 6); the greater relative importance of cut marks in almost all assemblages Table 6); and the high amount of intentionally broken bones indicate that final processing has occurred (Bunn et al., 1988; Kent, 1993; Lupo and O'Connell, 2002; Lyman, 1987, 1994).

Fat-oriented carcass processing is suggested by various lines of evidence, such as (a) the prevalence of elements with little meat and a moderate or low marrow content, or with fatty organs (Fig. 3); (b) the importance of percussion marks in the appendicular region associated with marrow procurement; (c) the negative correlation between the representation of long bone epiphyses and their bone grease content; and (d) the possible use of some vertebrae to render bone grease. This emphasis on grease extraction might be associated with the guanaco's lean meat, the low amount of subcutaneous fat that it provides, and the low amount of energy provided by other sources (carbohydrates). On the other hand, seasonal variation in guanaco fat level would explain extreme cases such as at the CCe1 site, where even the second phalanxes, some vertebrae and long bone ends were processed to extract lipids.

5.1.4. Choique

Choique played a secondary role in prehistoric steppe hunter-gatherers' diet. In contrast, historical descriptions (e.g. Musters, 1991) show that choique occupied a more important place in subsistence, probably due to the introduction of the horse and the stimulus given by the choique feather trade (Prieto, 1997). Before that, difficulties in its capture as well as the illnesses (e.g. salmonellosis) transmitted by these birds (Daciuk, 1978, p. 77) might have discouraged choique exploitation. Archaeological evidence shows hunting of adult animals and a marrow-oriented carcass processing. Other products exploited were meat and sinew, the latter probably used for manufactures as seen in historical sources (de Viedma, 1972). The presence of eggshells in all the sites indicates that this product was also consumed.

5.2. Constraints on prey exploitation

Among the constraints that may influence subsistence choices, human fat requirements are clearly reflected on the processing modes characterized above. Regardless of the environment characteristics, the human need of fats was the main factor in exploiting vertebrates, both large and small. In the steppe, lipids requirement shaped modes of faunal exploitation, as seen in the guanaco, choique and mountain viscacha bone assemblages. In the forest, even though the sample is smaller and reflects initial consumption instances, bone marrow exploitation is documented in both CP site ungulate assemblages as well as in the huemul at ASI. Lack of carbohydrates or focusing diet on wild animals explains the importance of grease among hunter-gatherers (Speth and Spielmann, 1983; Cordain et al., 2000). In inland Patagonia there are some edible plants, but they offer low amounts of energy. This characteristic contributes to create a scenario of a chronic scarcity of fat, which may explain the uniform temporal and spatial emphasis on its exploitation.

A second factor reflected in the exploitation modalities is animal prey yield and distribution. Both in the forest and in the steppe, the largest ungulates were the main faunal resources, whether for their taxonomic abundance or the meat and lipid quantities they represented. In the forest, only huemul and guanaco were exploited, dismissing pudú, a small cervid considered as a potential prey used in other forest archaeological sites (e.g. Velásquez and Adán, 2004). Furthermore, the differential distribution of huemul and guanaco (the former in the forest and the later in the steppe) explains taxonomic abundance. In the case of choique, risk of human illness and difficulty of procurement were more important than the potential yield.

Finally, the availability of ceramic technology is not reflected in guanaco exploitation in the Patagonian steppe (choique assemblages could not be compared due to sample size). If units of analysis with and without pot sherds are compared (see Table 1), no differences in axial anatomical representation (Fig. 3) or variations in bone grease exploitation are observed. Indeed, evidence of bone grease rendering in unit 5 at CCe1 suggests boiling before ceramics appeared, by using containers made of other raw materials such as plant fiber or animal skin. In terms of the discussion about ceramic function among Patagonian hunter-gatherers, Mena and Jackson (1991) propose that ceramics allowed grease extraction and conservation, whereas Borrero (1994–1995) considers that the scarcity of plant fuel (wood) seriously limited ceramic dispersal and affected the cost of grease rendering by boiling. Contrary to Mena and Jackson's (1991) hypothesis, the study case shows that there was not a direct relationship between ceramic availability and grease extraction and provides support to the idea that ceramics did not have a specific function in Patagonia (Borrero, 1994–1995).

6. Final remarks

In a context of an absence of supplementary energy sources beyond animal fats, it appears that need for grease emerged as the main factor in prey exploitation modes in NW Chubut. The low diversity of wild ungulates imposed constraints to human decisions, focusing subsistence on the largest prey with the best yield. The fat-oriented exploitation pattern began earlier than the appearance of ceramics, and thus this technological innovation did not impact on faunal processing.

The outcomes of this research are relevant on a local scale, but can also be integrated into the spectrum of hunter-gatherer subsistence strategies. Also, they can be applied to discuss some aspects of human occupation in forest environments, complementary between forest and steppe, and human strategies to cope with low energy environments. Therefore, emphasizing the particularities of NW Chubut environment does not mean fostering a local view. On the contrary, the aim is to widen the range of biological and cultural phenomena of continental and global significance.

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