Subsistence patterns during the Holocene in the Interserrana area (Pampean region, Argentina): Evaluating intensification in resource exploitation

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ABSTRACT

Intensification is defined as the process by which the total productivity per areal unit of land is increased at the expense of overall decreases in foraging efficiency. The Interserrana area is a large ecosystem of grasslands located in the Pampean region of Argentina inhabited by hunter–gatherers from the Late Pleistocene until recent times. The objectives of this paper are to characterize subsistence patterns in the Interserrana area during the Holocene, to compare these trends considering their chronology, and to evaluate if there was an intensification process in this sector of the Pampean region in the Late Holocene. Four faunal assemblages from this area were analyzed. Additionally, published information about local assemblages was compiled and incorporated into the discussion. Results indicate that hunter–gatherers used a generalized strategy during the Early Holocene and the first half of the Middle Holocene. During the second half of the Middle Holocene and the Late Holocene, the diet was strongly oriented to the consumption of guanaco, and an intensification process is not documented for the Interserrana area. The hypothesis to explain the changes in the diet is that there were variations in the guanaco local availability.

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Introduction

Intensification is defined as the ability of human populations to obtain more food in a given unit of time or space (Binford, 1983; Morrison, 1994) or, as used in this article, as a process by which the total productivity per areal unit of land is increased at the expense of overall decreases in foraging efficiency (Broughton, 1994, p. 501). In recent years, this term has been used in archaeology with the aim of evaluating changes related to subsistence strategies in foragers from different regions, like northwestern United States, Canada, and Oceania (Broughton, 1994; Morrison, 1994; Janetski, 1997; Minnegal and Dwyer, 1998; Betts and Friesen, 2004; Butler and Campbell, 2004; among others). In the Pampean region, during the Late Holocene there was a series of changes in subsistence as well as in technology and demography. Different authors have proposed that the interaction among these changes generated a process of complexity in the Pampean societies (Berón and Politis, 1997; Barrientos, 2001; Politis and Madrid, 2001; Politis et al., 2001; Quintana and Mazzanti, 2001; Madrid et al., 2002; Loponte et al., 2004; Martínez, 2006; Politis and

Barros, 2006; Salemme and Madrid, 2007; among others). Settlements in this period were characterized by an occupational redundancy, a lower mobility, and a higher frequency of residential camps (Berón and Politis, 1997; Martínez, 2006). Technological changes included greater variability of lithic assemblages and bone tools, and innovations of pottery-making and bow and arrow (Politis, 1986; Berón and Politis, 1997; Politis and Madrid, 2001; Bonomo, 2005; Martínez, 2006). Additionally, the number of exotic raw materials and goods grew, which suggests an increase in inter-regional contacts and long distance travels (Politis and Madrid, 2001; Quintana and Mazzanti, 2001).

Regarding subsistence changes, Martínez and Gutiérrez (2004) proposed a general model for the Pampean region. These authors consider that hunter–gatherers developed three strategies from the Late Pleistocene to the Late Holocene: (1) a *generalized regional economy* for the Late Pleistocene/Early Holocene period (12,000–6500 years BP), which considered a broad spectrum of exploited resources, including extinct fauna; (2) *specialized regional economies* with an emphasis on guanaco hunting for the Middle Holocene (6500–3500 years BP); and (3) a *diversification and intensification of areal economies* for the Late Holocene (3500–500 years BP), with an increase in the number of exploited species,

and in the use of small, medium, and big preys (Martínez and Gutiérrez, 2004). Available data for the last period indicate that it was not homogeneous, and some researchers divide it into the initial Late Holocene (*ca.* 3500–1000 years BP) and the Final Late Holocene (*ca.* 1000 years BP to the Hispanic–indigenous contact) (Quintana and Mazzanti, 2001).

The existence of an intensification process during the Late Holocene was proposed for most areas of the Pampean region (Quintana and Mazzanti, 2001; Martínez and Gutiérrez, 2004; Loponte et al., 2006; Escosteguy et al., 2012; Salemme et al., 2012). Nevertheless, for the Interserrana area Martínez and Gutiérrez (2004) noted that the repertoire of exploited animals remained similar from the Middle to the Late Holocene. Other researchers agree with this observation (Massigoge, 2007; Messineo, 2011), while Salemme and Madrid (2007) proposed an increase in faunal diversity during the Late Holocene, according to an intra-site study (Tres Reyes 1 site). Lack of detailed faunal studies determining the intensification in the Interserrana area has made it difficult to settle this question. In this context, the objective of this study was to characterize subsistence patterns in the Interserrana area during the Holocene, and to compare these trends considering their chronology to evaluate if there was an intensification process in this sector of the Pampean region in the Late Holocene.

Characteristics of the study area

The Pampean region of Argentina is a large ecosystem of grasslands located in the eastern part of southern South America, and it was inhabited by hunter–gatherers from the Late Pleistocene until recent times (Politis, 2008). The Pampas are subdivided into the Humid Pampa (East) and the Dry Pampa (West) subregions (Fig. 1). The former has a temperate-humid climate without a dry season but with a warm summer, and an annual rainfall of approximately 600–1000 mm (Burgos, 1968; Daus, 1968). Politis (1986) divided the Humid Pampa into seven areas, based on archaeological and physiographic characteristics: the North, the Salado Depression, the Interserrana, the Tandilia Ranges, the Ventania Ranges, the West, and the South (Fig. 1). The Interserrana area, which comprises the grasslands between the two ranges (Tandilia and Ventania), is a plain with a wide and low watershed, extending over 140 km. Its basins are drained by rivers or streams whose headwaters are in the ranges, although other courses originate in the plain itself. Watercourses flow into the ocean or lakes, dammed by coastal dunes (Fidalgo et al., 1991; Zárate and Rabassa, 2005).

Typical animals of the Pampean region inhabit open grasslands (Ringuelet, 1961). Its most conspicuous mammals are rodents, like the Patagonian hare (*Dolichotis patagonum*), the plains viscacha (*Lagostomus maximus*), the tuco-tuco (*Ctenomys* sp.), the cavy (*Cavia* sp. and *Microcavia* sp.), and the capybara (*Hydrochoerus hydrochaerys*). Common carnivores include the weasel (*Galyctis cuja*), the skunk (*Conepatus chinga*), and different species of foxes, felids, and opossums (Cabrera and Willink, 1980). Today, some mammals such as guanaco (*Lama guanicoe*) and Pampean deer (*Ozotoceros bezoarticus*) are almost absent from the region, although they were abundant in the past (Merino, 2003; Politis et al., 2011). There is also a large number of arboreal and aquatic birds, like partridges
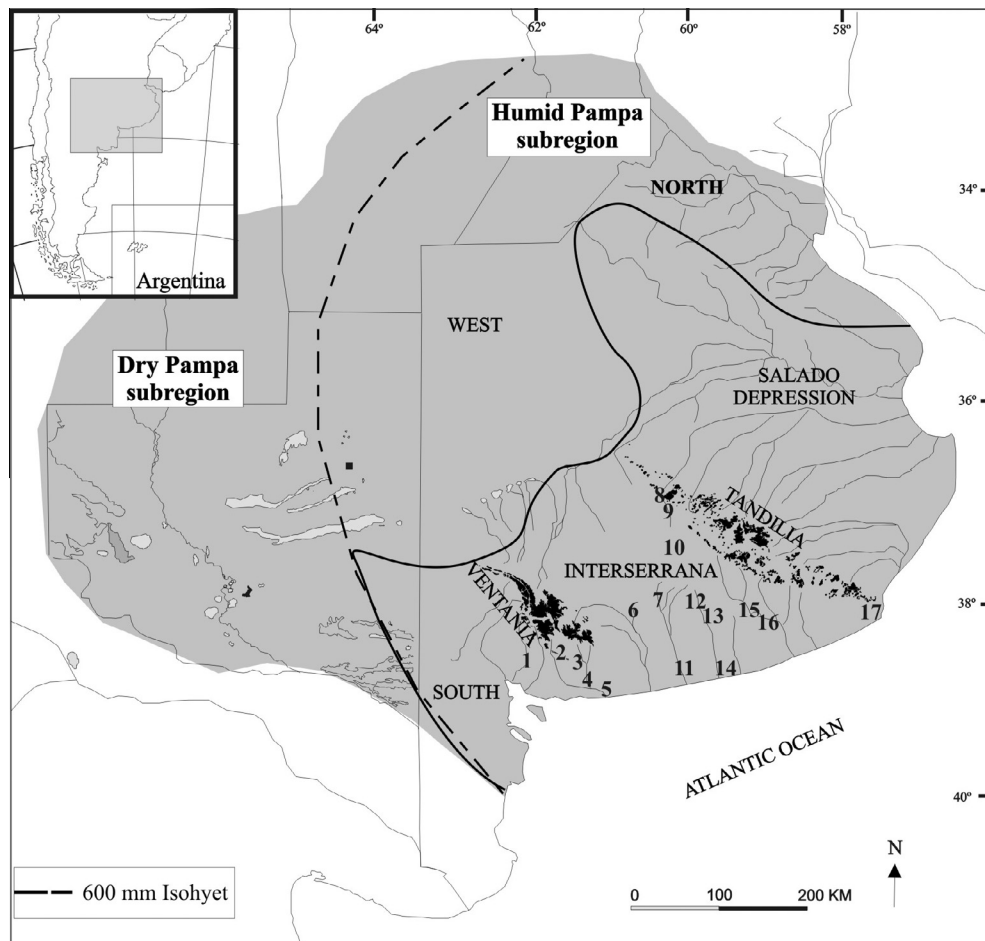

Fig. 1. Map of the Pampean region of Argentina showing the subregions and archaeological areas. The numbers represent the archaeological sites discussed in this article: 1 – Paso Vanoli; 2 – La Toma; 3 – Paso Mayor; 4 – Puente de Fierro; 5 – Monte Hermoso; 6 – Tres Reyes 1; 7 – Arroyo Seco 2; 8 – Calera; 9 – Empalme Querandíes 1; 10 – La Barrancosa 1; 11 – Claromecó 1; 12 – Las Brusquillas 1; 13 – Cortaderas; 14 – El Guanaco 2; 15 – Paso Otero 3; 16 – Paso Otero 4; 17 – Alfar.

of the genera *Rynchotus* and *Nothura*, martinetas (*Eudromia* sp.), and ducks (genera *Anas* and *Netta*), among others (Cabrera and Willink, 1980). The greater rhea (*Rhea americana*) is the largest bird in the region (Tambussi, 1995). Finally, there are different species of armadillos, such as the hairy armadillo (*Chaetophractus villosus*), the Southern long-nosed armadillo (*Dasypus hybridus*), and the dwarf armadillo (*Zaedyus pichiy*) (Vizcaíno et al., 1995).

Materials and methods

Faunal materials from four open-air archaeological sites of the Interserrana area were analyzed: Paso Otero 4 (District of Necochea), La Toma (District of Coronel Pringles), Empalme Querandíes 1, and Calera (both located in the District of Olavarría). The first three are multiple activity sites, where tasks such as lithic tool maintenance and animal butchery were performed (Álvarez et al., 2013; Messineo et al., 2013; Álvarez and Salemme, 2014). In the case of Calera site, previous analyses indicate that the deposit was formed as the result of rituals carried out during the Late Holocene. These ceremonies and feasts included the presence of items from distant places, suggesting several events of band aggregation (Politis et al., 2005; Messineo and Politis, 2007; Álvarez, 2009).

In the case of Paso Otero 4, the archaeological deposit was divided into the lower levels (PO4ll) and the upper levels (PO4ul) (Álvarez et al., 2013). The criteria used were the presence of extinct fauna exclusively in PO4ll and paleoenvironmental changes, such as warmer and more humid conditions in the PO4ul, indicated by pollen and phytoliths (Gutiérrez et al., 2011). For La Toma site, the lower levels (LTll) were separated from the upper component (LTup) by a hiatus (Álvarez and Salemme, 2014). The assemblage of Empalme Querandíes 1 was considered a single sample (EQ1), since stratigraphic and archaeological characteristics did not make

it possible to separate components or groups of levels (Messineo et al., 2013). Calera site consisted of at least four pits containing archaeological remains. These were named pit 1, which was internally separated by a limestone slab level in pit 1 upper assemblage (Cp1ua) and pit 1 lower assemblage (Cp1la), pit 4 (Cp4), pit 2 (Cp2), and pit 3 (Cp3) (Politis et al., 2005). All the faunal materials were analyzed by the author, except for the micro-vertebrate remains from Paso Otero 4 (studied by A.P. Alcaraz; Álvarez et al., 2013) and the avian and micro-vertebrate materials from Calera (Scheifler, 2012). Since faunal analyses for Calera are complete for Cp2, this was the only feature used for comparing taxonomic measures. Chronology for each sample, as well as the total analyzed NISP, is presented in Table 1.

Faunal specimens were determined at different taxonomic/anatomic levels, through the use of faunal reference collections. Measures of NISP (Number of Identified Specimens) and MNI (Minimum Number of Individuals) were obtained for all taxa (Grayson, 1984; Klein and Cruz-Uribe, 1984; among others), while skeletal part profiles were constructed only for guanaco considering also MNE (Minimum Number of Elements), MAU (Minimal Anatomic Units), and % MAU (*e.g.,* Binford, 1978; Klein and Cruz-Uribe, 1984). Different taphonomic analyses were performed, which are not detailed in this paper but can be found in the references (Álvarez, 2009; Scheifler, 2012; Álvarez et al., 2013; Álvarez and Salemme, 2014; Messineo et al., 2013). These include the register of different variables, as well as the evaluation of destruction processes mediated by the bone mineral content. Since most of the sites are located in flood plains, a model was applied to evaluate hydrodynamic sorting of guanaco bones of different ages (Kaufmann et al., 2011). In addition, variables related to the identification of human butchery, such as thermal alteration, type of fracture, and cut marks, were recorded (Binford, 1981; Shipman, 1981; Johnson, 1985; David, 1990). Guanaco skeletal part profiles

Table 1
NISP, chronology, and dated material for each analyzed sample. Only dates associated with archaeological materials are presented.

Sample	NISP	Chronology	Dated material	References
Paso Otero 4 lower levels (PO4ll)	5318	8913 ± 49	OMS (residues)	Gutiérrez et al. (2011) and Álvarez et al. (2013)
		8305 ± 67	OMS (humates)	
		8760 ± 160	OMS (residues)	
		8331 ± 65	OMS (humates)	
		8556 ± 65	Charcoal	
		8075 ± 66	OMS (humates)	
		6395 ± 79	OMS (residues)	
		8735 ± 48	OMS (humates)	
		6168 ± 43	OMS (residues)	
		7729 ± 48	OMS (residues)	
		7713 ± 73	OMS (humates)	
Paso Otero 4 upper levels (PO4ul)	11,375	6739 ± 48	OMS (residues)	
		6668 ± 55	OMS (humates)	
		5559 ± 43	OMS (residues)	
		5503 ± 43 H	OMS (humates)	
		4561 ± 41	OMS (bulk)	
La Toma lower levels (LTll)	730	3523 ± 32	Guanaco bone	Politis (1986) and Álvarez and Salemme (2014)
		2075 ± 70	Human bone	
		1920 ± 34	Guanaco bone	
Empalme Querandíes 1	77,913	3095 ± 50	Guanaco bone	Messineo et al. (2013)
		2816 ± 49	Guanaco bone	
		2052 ± 62	Guanaco bone	
Calera Pit 1 lower assemblage (Cp1la)	283	3390 ± 170	Guanaco bone	Politis et al. (2005)
Calera Pit 1 upper assemblage (Cp1ua)	872	2232 ± 55	Guanaco tooth	
		1748 ± 42	Guanaco bone	
Calera Pit 4 (Cp4)	369	3160 ± 320	Guanaco tooth	
Calera Pit 2 (Cp2)	5152	3055 ± 66	Guanaco bone	
		3008 ± 46	Guanaco bone	
		2075 ± 44	Guanaco bone	
La Toma upper component (LTuc)	2250	995 ± 65	Charcoal (hearth)	Politis (1986)

References: OMS = organic matter of sediment.

were correlated with the Guanaco Meat Utility Index (Borrero, 1990) and the Guanaco Marrow Index (Mengoni Goñalons, 1999) through correlations of Spearmańs rho.

Archaeological indicators of intensification

To evaluate the existence of an intensification process in the Interserrana area, the following indicators were used.

Changes in ungulate skeletal part profiles

Hunter–gatherers tend to exploit resources around the residential camp because the transport costs are low. When availability of local resources declines, butchering costs tend to increase in order to maximize the utility of the resource (Winterhalder, 2001). However, both obtaining lower ranked resources close to the camp and searching for higher ranked ones farther away are suitable strategies. Moreover, hunter–gatherers could include previously ignored preys in their diet (Rowley-Conwy and Layton, 2011).

A common strategy among hunter–gatherers is to become more selective when choosing which skeletal parts will be transported to the central campsite (Nagaoka, 2005). In these cases, the ungulate skeletal part profiles from residential camps would present high utility parts, given the decline of these animals in the landscape (Broughton, 1997). Nevertheless, it is important to mention that butchering practices are also imbued with heritage and tradition, so these variables also affect the decisions on subsistence.

Changes in the butchery indicators

When foraging efficiency declines, hunter–gatherers will obtain more calories from the skeletal parts transported to the residential camp, which is achieved by extracting marrow and bone grease (Nagaoka, 2005). The intensive processing of bones for marrow and fat requires more effort than processing meat and is an indicator of long-time residence in a given patch (Burger et al., 2005).

Changes in assemblage fragmentation were evaluated considering the methodology proposed by Lyman (1994) and Wolverton (2002). The intensity of fragmentation in guanaco bones was measured by determining the ratio of NISP to MNE (NISP:MNE, excluding complete elements) considering that the higher the anatomical completeness, the smaller the difference between both measures (Lyman, 1994, 2008). The extent of fragmentation was estimated by counting how many specimens were fractured and how many were complete, and by calculating the percentage of anatomically complete elements expressed as % whole (Lyman, 1994, 2008). As stated by Wolverton (2002: 89–90), marrow can only be extracted by fragmenting bones. Thus, the lower the % whole, the higher the extraction of marrow. On the other hand, the extraction of grease requires more fragmentation, so the greater NISP:MNE ratio indicates the higher grease extraction.

Changes in the frequency of big and small species

A decrease in the foraging efficiency is indicated by lower values of indexes that measure frequencies of high ranked species in relation to low-ranked ones (Broughton, 1994; Nagaoka, 2005). Resource rankings can be established on the basis of *proxy* measures (mainly body size) when calculating actual energetic returns is not possible (Broughton, 1994). Artiodactyl Index (AI) shows the efficiency in the use of vertebrates through the frequency of small-sized animals (low-ranked) in relation to artiodactyls (high-ranked) and can be easily calculated using NISP (Bayham, 1979; Broughton, 1994; Lyman, 2008). The formula [$\sum$NISP artiodactyls/$\sum$NISP (artiodactyls + lagomorphs)] was used,

but lagomorphs were replaced with similar sized animals such as coypu, Patagonian hare, plains viscacha, and armadillos, and including guanaco and Pampean deer in the artiodactyl category. Species with clear evidence of anthropic use were exclusively considered. Some authors have noted that return rate is also dependent on the density of resources, as well as the failure probability, and the available technology, among other factors (Broughton, 1997; Ugan, 2005; Bird et al., 2009). However, body size has proved to be a reliable criterion for evaluating resource rankings and efficiency in the use of vertebrates when combined with other lines of evidence (Broughton et al., 2011).

Changes in faunal diversity and taxonomic richness

When animalś repertoire and site functionality remain similar over time, changes in faunal diversity can be indicative of an intensification process. If high-ranked preys are difficult to obtain, low-ranked animals are incorporated into their diet. Ntaxa refers to taxonomic richness or the number of identified species. Taxa were counted considering the different taxonomic levels reached when these were non-overlapping (Grayson, 1991). For example, *Lama guanicoe* (species) and Camelidae (Family), were both equal to one when present in the same sample.

Shannon–Wiener Index (Sh–W) was used to estimate Diversity. The result is a value obtained from natural logarithms of the proportion of specimens. This index was calculated using the statistical program *PAST* (version *2.08*). The formula is $H = -\Sigma P_i (\text{nl} P_i)$, where P_i is the proportion of the i taxa in the assemblage. The result varies between zero and the base of the used logarithm and is complementary with the AI. Again, for AI and Sh–W, species with clear evidence of anthropic use were exclusively considered.

Results

Taxonomic structure of the assemblages

Results of the taxonomic structure of the samples are presented in Table 2, where this information was superimposed with available data about geographic distribution of taxa, considering the chronology of each archaeological sample. The totals for the assemblages, including unidentified fragments, are available in the references (Álvarez, 2009; Scheifler, 2012; Álvarez et al., 2013; Messineo et al., 2013; Álvarez and Salemme, 2014). Data used in this paper do not include eggshells, armadillo plates, and unidentified specimens. In all the samples, the best represented remains are those of guanaco bones, except for PO4ll, where plains viscacha specimens are more abundant (Table 2). Pampean deer and greater rhea were both exploited in all assemblages. Armadillos and rodents were also consumed in all samples, while the use of carnivores and small birds was variable and depended on the site (Table 2).

Guanaco skeletal part profiles

Guanaco skeletal part profiles showed that there was a selection of elements for its transport in all samples. There were significant positive correlations with the Meat Utility Index for the samples PO4ll, Cp4, and Cp1ua, while for Cp2 the result was very close to the limit of significance (Table 3). Regarding Marrow Index, the only significant positive correlation was obtained for Cp2 (Table 3).

With the aim of evaluating changes in the guanaco skeletal part profiles, a ternary graph was constructed by means of the program PAST and considering guanaco MAU values. Because only three variables are required in this kind of analyses, MAU was recalculated considering the forelimb, the hind limb, and the axial skeleton (Fig. 2). Results indicate

Table 2
Taxonomic structure of the assemblages.

	Taxa	Common name	PO4ll	PO4ul	LTll	EQ1	Cp2	LTuc
Mollusca	Gastropoda (marine)	Gastropod	7	117	3	4	-	9
	Bivalvia (marine)	Bivalve	-	-	2	1	-	-
	Glycimeris longior	Bittersweet clam	-	1	-	-	-	-
	Adelomelon brasiliana	Black snail	-	-	-	-	1	1
Artio	*Lama guanicoe*	Guanaco	124*	426*	382*	629*	1649*	182*
	Ozotoceros bezoarticus	Pampean deer	71*	65*	33*	84*	135*	143*
Carnivora	Canidae	Canid	29*	32*	-	16	63*	1*
	Felidae	Felid	9*	1*	4	-	-	-
	Dusicyon avus	Extinct fox	1	-	-	-	1	-
	Puma concolor	Puma	-	-	-	-	-	11*
	Conepatus sp.	Hog-nosed skunk	2*	21*	-	3	-	1*
Rodentia	*Dolichotis patagonum*	Patagonian hare	2	1	4*	2	-	9*
	Lagostomus maximus	Plains viscacha	144*	118*	6	63*	17	6
	Myocastor coypus	Coypu	-	-	-	1*	-	-
Dasypodidae	*Chaetophractus villosus*	Hairy armadillo	116*	78*	9*	16*	plates*	98*
	Zaedyus pichiy	Dwarf armadillo	plates*	plates*	2*	plates*	plates*	11*
	Dasypus hybridus	Southern long-nosed armadillo	-	-	-	plates*	plates*	plates
	Tolypeutes matacus	Three-banded armadillo	-	-	-	plates*	-	-
	Eutatus seguini	Extinct armadillo	14*	-	-	-	-	-
Aves	*Rhea americana*	Greater rhea	20*	7*	7*	7*	4*	7*
	Tinamidae	Tinamous and partridges	9*	8	-	5	10	-
	Anatidae	Ducks, geese, and swans	-	1	-	-	7*	-
	Rallidae	Crakes, cotos, and gallinules	-	-	-	-	21	-
	Accipitridae	Diurnal birds of prey	-	-	-	-	97	-
	Strigidae	Typical owls	-	-	-	-	1*	-
	Charadriiformes	Waders, gulls, and auks	-	-	-	-	3*	-
	Passeriformes	Songbirds	-	-	-	-	97	-
	Psittaciformes	Parrots	-	-	-	-	2	-
R	*Tupinambis* sp.	Tegu lizard	-	-	3	-	-	-

References: black = unavailable species; grey = no reliable data about availability; * = evidence of human consumption; Artio = Artiodactyla; R = Reptilia.

Table 3
Results of statistical correlations between guanaco skeletal part profiles and meat utility and marrow indexes.

Sample	MUI (Borrero, 1990)			MI (Mengoni Goñalons, 1999)		
	Rs	P	Result	Rs	p	Result
PO4ll	0.390	0.040	Significant positive	−0.212	0.733	Non-significant negative
PO4ul	0.305	0.114	Non-significant positive	0.542	0.241	Non-significant positive
LTll	−0.310	0.108	Non-significant negative	−0.485	0.297	Non-significant negative
EQ1	0.129	0.509	Non-significant positive	0.085	0.802	Non-significant positive
Cp2	0.401	0.052	Non-significant positive	0.885	0.016	Significant positive
Cp1la	0.090	0.67	Non-significant positive	0.428	0.355	Non-significant positive
Cp1ua	0.716	8.2054E−05	Significant positive	0.724	0.122	Non-significant positive
Cp4	0.604	0.001	Significant positive	0.637	0.2	Non-significant positive
LTuc	0.228	0.242	Non-significant positive	0.142	0.713	Non-significant positive

References: grey = significant positive correlation.

that most of the samples presented a similar proportion of the three parts. Nevertheless, the PO4ll assemblage shows a predominance of the axial elements. A similar but less pronounced trend was observed for PO4ul assemblage. On the other hand, Cp4 has the lowest proportion of axial bones, while the other assemblages are distributed in the central

part of the graph (Fig. 2). Taphonomic analyses carried out on the sites indicate that skeletal part profiles were not significantly conditioned by agents and/or processes affecting bone preservation differentially (Álvarez, 2009; Messineo et al., 2013; Álvarez and Salemme, 2014). However, for PO4ll hydrodynamic sorting could have subtracted low density
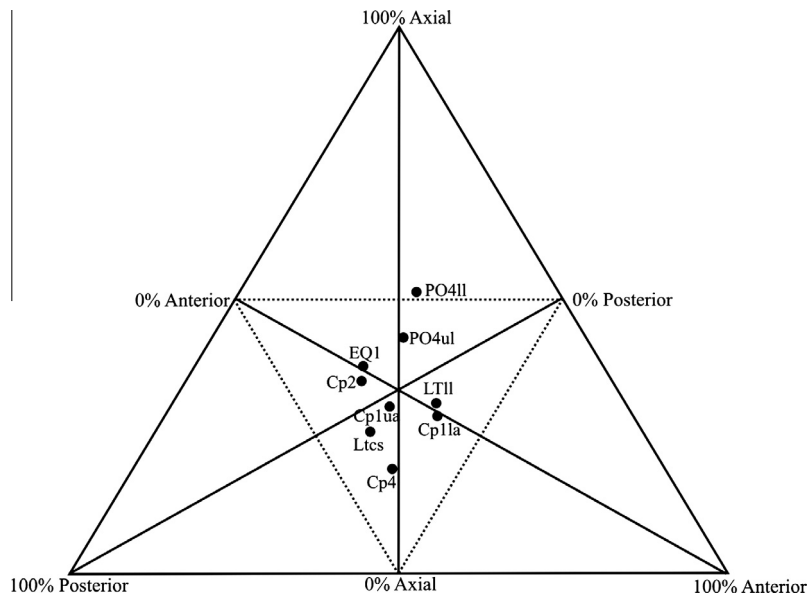
Fig. 2. Ternary graph showing the proportion of guanaco skeletal units per sample.
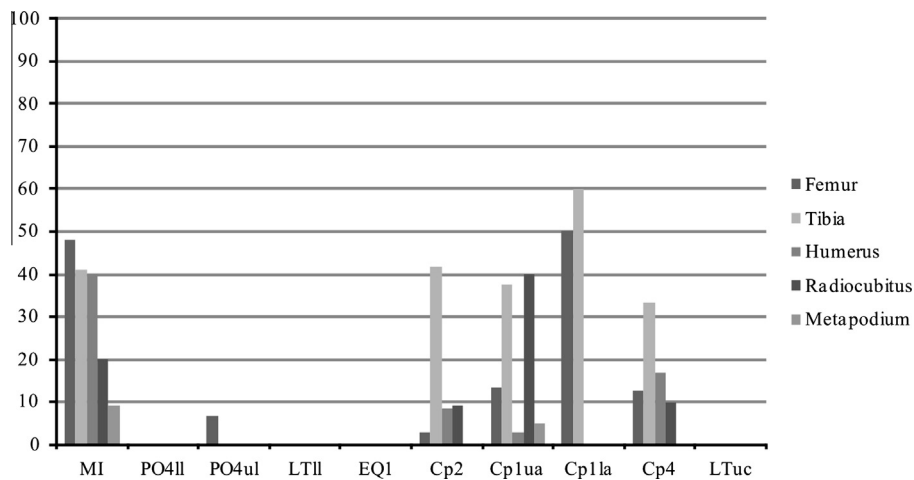

Fig. 3. Guanaco Marrow Index values (Mengoni Goñalons, 1999) and % whole for long bone shafts in all the samples.

elements from the assemblage (*e.g.*, vertebrae); although if fluvial transport produced a bias in this sample, the general trend would have been even more pronounced (Álvarez et al., 2013).

Taxonomic richness, diversity, and artiodactyl index

Results show that the highest Ntaxa was obtained for the earliest sample (PO4ll; *N* = 11), while it was *N* = 9 for PO4ul. The Late Holocene assemblages present variable values, the highest being for Cp2 (*N* = 10), followed by LTuc (*N* = 9), EQ1 (*N* = 9), and LTll (*N* = 6). The Sh–W Index results were as follows: PO4ll = 1.9; PO4ul = 1.6; LTll = 0.53; Cp2 = 0.56; EQ1 = 0.7; and LTup = 1.41. Values for the AI were as follows: PO4ll = 0.42; PO4ul = 0.73; LTll = 0.96; Cp2 = 0.97; EQ1 = 0.89; and LTuc = 0.82.

Fragmentation intensity of guanaco bones

Since anthropic fractures can be reliably recognized only in the long bone shafts, these elements were exclusively considered when the extent of fragmentation was analyzed. Results of the % whole were compared with available data about marrow content

for guanaco bones (Mengoni Goñalons, 1999). All samples showed that % whole values were close to zero for the long bone shafts, except for the assemblages of Calera site (Fig. 3).

Regarding the intensity of fragmentation, although the origin of the fractures (natural *vs.* cultural) is hard to determine, all elements were included in calculations since the identified taphonomic agents did not fracture bones intensively (Álvarez, 2009; Álvarez et al., 2013; Messineo et al., 2013; Álvarez and Salemme, 2014). The only excluded bones were the scapula and the skull because they tend to break easily by post-depositional processes. Fig. 4 shows the results of some of the axial and appendicular skeletal units. The axial skeleton does not show different trends over time in the intensity of fragmentation; on the contrary, values are similar for all samples (Fig. 4a) and the same applies to the long bones (Fig. 4b).

Discussion

The analysis of the guanaco skeletal part profiles indicated that this ungulate was not always complete when it entered the sites. Selection of anatomical units would have been guided by their
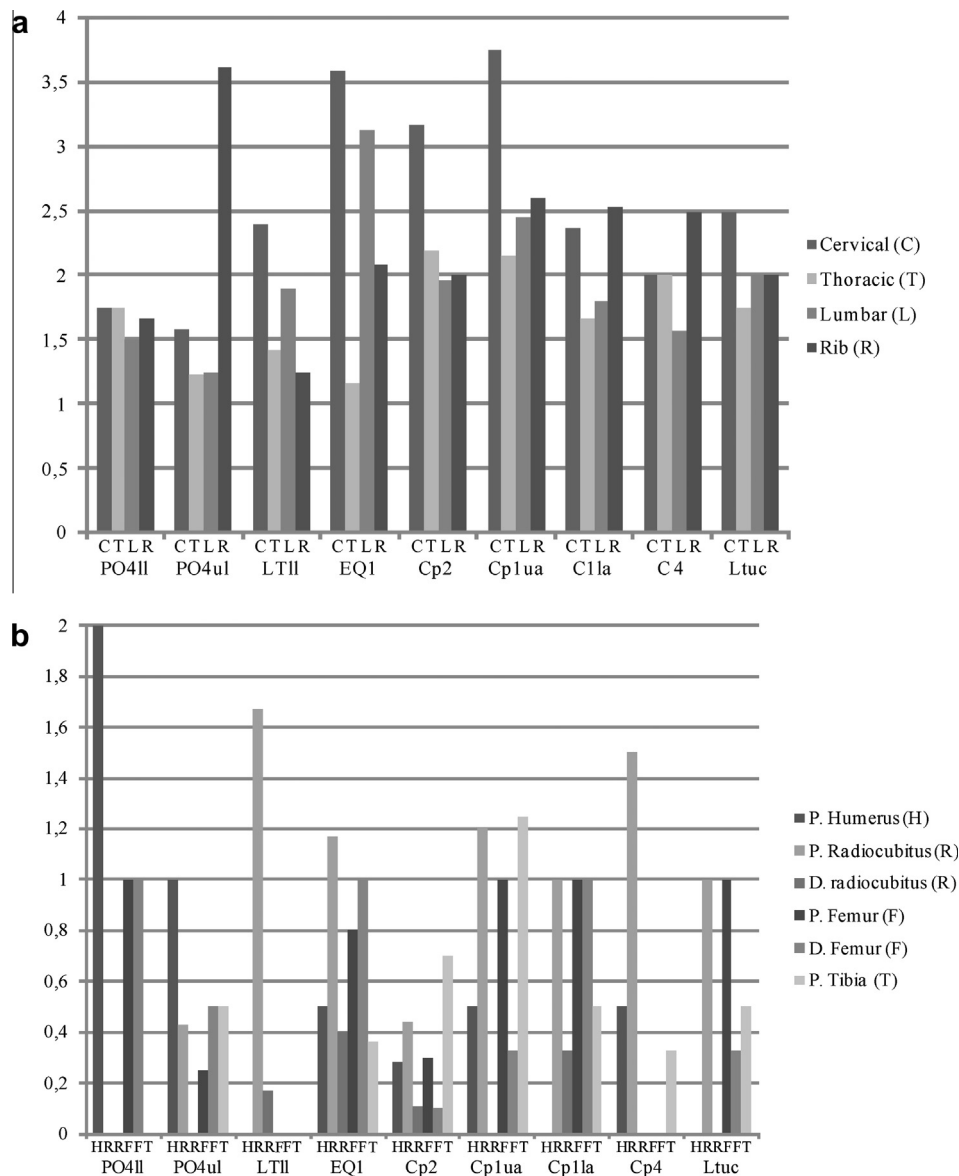
Fig. 4. (a) NISP:MNE for guanaco axial elements; (b) NISP:MNE for guanaco appendicular elements with high content of bone grease. References: P = proximal; D = distal.

nutritional value in PO4ll, where the presence of high-ranked body parts could be related to a strategy less focused on artiodactyls, and therefore more selective on guanaco bone transportation to the residential camp (Nagaoka, 2005). In Calera site, most samples showed a significant positive correlation with the nutritional value of elements, which is consistent with the functionality proposed for the site. Assemblages resulting from feasts are characterized by the predominance of high-ranked elements (Kelly, 2001; Pauketat et al., 2002; Yerkes, 2005; among others), associated with behaviors of food waste (Hayden, 2001) or consumption of luxury food (*sensu* Ervynck et al., 2003). The rest of the guanaco skeletal part profiles showed a similar proportion of the forelimb, the hind limb, and the axial skeleton, and did not present significant positive correlations with the MUI.

Regarding the extent of fragmentation, in all cases the shafts had a higher % whole than ends. The high values obtained for some elements (*e.g.*, humerus, tibia) could be mainly related to the bone marrow acquisition and, to a lesser degree, to the use of bones as raw material for tools, as well as a combination of both. The extent of fragmentation was similar for all the samples with different

chronologies. Again, Calera site was an exception, as its assemblages showed low marrow use. Different authors noted that in feasting contexts, bone marrow is underexploited, contrary to what is observed in household contexts (Potter, 2000; Hayden, 2001; Pauketat et al., 2002; Marciniak, 2005; among others).

In general, values of NISP:MNE are close to two, indicating that elements are divided into two halves (Lyman, 2008). These results do not coincide with the use of bone grease for any of the samples. While optimal size of fragments for obtaining bone grease is unknown, it is assumed that fragmentation should be much more intensive than that used for marrow extraction (Wolverton, 2002). Outram (2001) noted that axial trabecular bone fractured with this aim would be represented by very small fragments. For the Pampean region, it was proposed that appearance of pottery during the beginning of the Late Holocene (Politis et al., 2001) generated a new method of cooking food, boiling, which made it possible to recover a larger amount of nutrients (Politis and Madrid, 2001; González, 2005). In this respect, analyzed samples did not exhibit high NISP:MNE values and these numbers were similar over time. While pottery could have been used for fat acquisition,

it was not used for the recovery of bone grease. Intensity of fragmentation did not show significant changes related to this process. This is different from what occurs in other areas of the Pampean region, such as the South (Stoessel, 2012) and the North (Mucciolo, 2010), where ceramic receptacles were used for this purpose.

Diversity and taxonomic richness showed variations in relation to the chronology of the samples. At this point it is important to consider that most of the species with evidence of human butchery did not change their distribution because of environmental factors in the Pampean region. Exceptions are the extinction of the armadillo *Eutatus seguini* in the Early Holocene, the incorporation of the Southern long-nosed armadillo in the Late Holocene, and variations in the distribution of the three-banded armadillo during the Holocene (Vizcaíno et al., 1995; Abba and Vizcaíno, 2011).

The highest taxonomic richness was obtained for the earliest sample, and it decreases toward the Middle and Late Holocene. Diversity values are also high for the early assemblages and diminish in the Late Holocene, and the contrary occurs with the AI. Since the aim of this study was to evaluate the subsistence patterns in the Interserrana area, as many samples as possible were included from published references when they met the following criteria: a) detailed analyses of materials, both recorded *in situ* and recovered through the screen-washing of sediments; b) available NISP data for each taxa; c) at least one radiocarbon date; d) materials in stratigraphic context. Ntaxa, Sh–W, and AI were calculated, including only those species with evidence of human butchery (Table 4). When there was more than one radiocarbon date, the mean was used to make a graphic representation containing a chronological axis. Nevertheless, it represents a broader period of time and interpretations are not conditioned to that number. These cases correspond to the samples analyzed in this paper (see dates in Table 1) and the Paso Mayor site.

Results of Sh–W and AI for the analyzed samples, together with those from the cited papers, are shown in Fig. 5. This graph indicates that one of the earliest samples (PO4ll) presents the highest values of Sh–W and AI. Nevertheless, these values are not very pronounced for El Guanaco site 2. The incorporated assemblage corresponding to the Middle Holocene (Paso Mayor; Frontini, 2012) shows a high AI and a low Sh–W, similar values to those observed for the initial Late Holocene. In this sense, the significant increase in artiodactyls' contribution to diet observed for the Late Holocene would be already established at *ca.* 4500 years BP (between *ca.*

5800 and 3800 years BP; Frontini, 2012). The exceptions to this trend are sites whose functionality is not multiple activity camps. Puente de Fierro has been interpreted as a prolonged occupation site inhabited by a higher number of individuals with low mobility, and therefore would be different from the rest of the residential camps in the region (Frontini, 2012). La Barrancosa 1 is also another atypical sample with extreme values of AI and Sh–W (one and zero, respectively). Nevertheless, in this case the site functionality is a specific location for guanaco butchery (Messineo, 2003). In the *ca.* 1000 years BP, there is a slight increase in Sh–W for LTuc, although this change is not observed for Paso Vanoli and Claromecó 1 sites. In general, results for AI during the Final Late Holocene are a little lower than those in previous periods (Fig. 5).

Similar cases to that of the Interserrana area were registered in a number of regions of North America. In Washington (Lyman, 1992), the southern High Plains (Holliday, 1989; Meltzer, 1999), and the Great Basin (Grayson, 2000; Broughton and Bayham, 2003) Middle Holocene climate changes affected mammalian community richness and evenness declined substantially, as a consequence of the increased aridity. Hot and dry climate conditions, together with drought, significantly affected the population densities of artiodactyls (Broughton and Bayham, 2003). This scenario required a diet breadth strategy, which included low-ranked plants and animals. Moreover, in some areas there is register of well-digging to tap underground water (Meltzer, 1999). Broughton et al. (2008) have noted that climatic seasonality played a fundamental role in driving variation in the densities of artiodactyls. In these respects, paleoenvironmental studies for the Pampean plains indicate that conditions previous to *ca.* 6000 years BP were characterized by dry environments. Evidence indicates dry conditions and more saline and shallower water bodies with periods of desiccation (Osterrieth et al., 2008; Zárate et al., 1998; Bonomo et al., 2013). Furthermore, most of the animals were adapted to arid to semiarid conditions during this period (Tonni and Cione, 1995; Tonni et al., 1999). Accordingly, the sample with the highest faunal diversity (PO4ll) is the only one for which the presence of a water well associated with *ca.* 8500 years BP was identified (Gutiérrez and Martínez, 2010). Toward *ca.* 6000/5000 years BP there was an increase in wetness, related to the *Optimum Climaticum* (also called Altithermal). Analyses on pollen, phytoliths, diatoms, and mollusks indicate valley lithofacies, which would have been subject to frequent floods, as well as lacustrine environments with

Table 4
Ntaxa, Sh–W, and AI values for the used samples.

Sample	Ntaxa	Sh–W	AI	Chronology ($\bar{x}$)	References
El Guanaco site 2	5	0.86	0.91	8171	Frontini (2012)
Paso Otero 4 lower levels	11	1.9	0.42	7978	Álvarez et al. (2013)
Paso Otero 4 upper levels	9	1.6	0.73	6057	Álvarez et al. (2013)
Alfar	5	0.43	NA[a]	5704	Bonomo and León (2010)
Paso Mayor Yacimiento 1, site 1, lower levels	5	1.02	0.81	4581	Frontini (2012)
Paso Otero 3	3	0.53	0.95	3850	Martínez (2006)
Las Brusquillas 1, lower levels	3	0.22	1	3334	Massigoge (2012)
Paso Mayor Yacimiento 1, site 1, upper levels	3	0.79	0.72	3297	Frontini (2012)
La Toma lower levels	6	0.53	0.96	2721	Álvarez and Salemme (2014)
Calera pit 2	10	0.56	0.97	2696	Álvarez (2009) and Scheifler (2012)
Empalme Querandíes 1	9	0.7	0.89	2654	Messineo et al. (2013)
Tres Reyes 1 lower levels	3	0.39	0.98	2470	Salemme and Madrid (2007)
Cortaderas	6	0.89	0.91	2270	Massigoge (2007)
Tres Reyes 1 upper component	3	0.53	0.92	2151	Salemme and Madrid (2007)
Puente de Fierro	6	1.25	0.53	2042	Frontini (2012)
La Barrancosa 1	1	0	1	1676	Messineo (2003)
La Toma upper component	9	1.41	0.82	995	Álvarez and Salemme (2014)
Claromecó 1	5	0.65	0.84	800	Bonomo et al. (2008) and C. León (pers. com.)
Paso Vanoli[b]	2	0.42	0.85	714	Frontini (2012)

[a] AI was not calculated for this site because of the low representation of guanaco in relation to the otariids.
[b] Despite the low number of specimens, this sample was included because this period is scarcely represented.
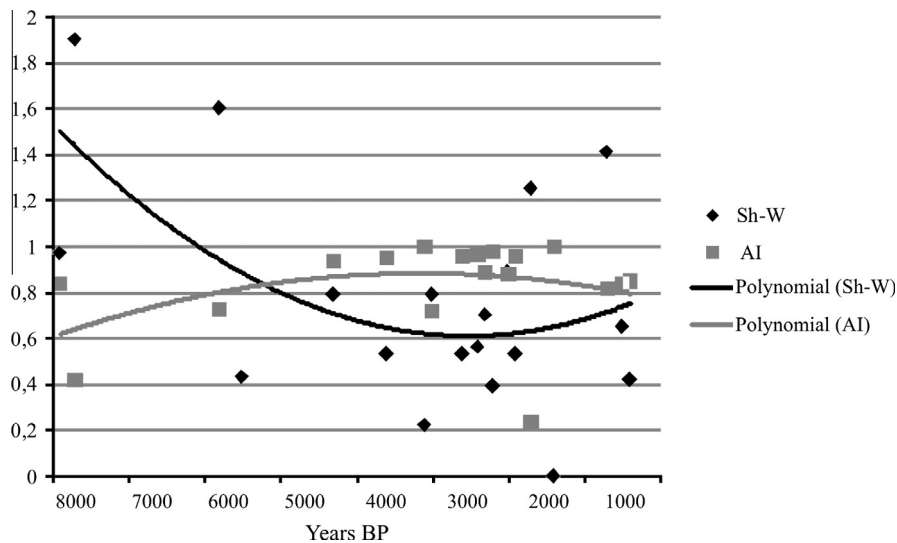
Fig. 5. Sh–W and AI results of the samples shown in Table 4.

wet conditions, and evidence of temporary water bodies, probably linked to creek and river flood margins (Quatrocchio and Borromei, 1998; Grill et al., 2007; Steffan, 2008; Gutiérrez et al., 2011). Taking into account these characteristics, it is important to evaluate if there were variations in the population densities of guanaco in the past.

Guanaco is a generalist herbivore able to consume most of the available plant species (Puig, 1995). According to Nugent et al. (2006), the size and density of the guanaco groups are conditioned by the heterogeneity of grasses and shrubs in the environment, as well as by the presence of competitors and the risk of predation. Studies developed by Saba et al. (1995) in different regions of Patagonia indicated that inanition constitutes the main cause of death of guanacos, related to the poor forage conditions during the winter. In this sense, climate is an important cause of mortality in guanacos, mainly because of prolonged snow cover or drought (Saba et al., 1995). The carrying capacity of the environment determines the number of guanacos that can be supported, without deteriorating pasture. When the density of individuals is small, there is a greater separation among the populations, and the habitat fragmentation conditions the social structure of guanaco (De Lamo and Del Valle, 1999).

Unfortunately, available studies dealing with guanaco paleodemography are almost nonexistent. However, there is an attempt to reconstruct paleoenvironmental conditions in the pampean region, and thus generate a distribution model for this and other ungulates. Politis et al. (2011) have used species distribution models with museum bone collection. These authors inferred paleoclimatic conditions during part of the Late Holocene, and could define the areas of overlapping among guanaco, pampean deer, and marsh deer. Furthermore, Weinstock et al. (2009) studied the extinction of *Lama gracilis* (extinct camelid), currently believed to correspond to *Vicugna vicugna* (vicuña) (Weinstock et al., 2009). These authors proposed that the establishment of modern climatic patterns in Patagonia at the beginning of the Holocene, possibly together with the contribution of human hunting, decimated populations of vicuñas, leading to their extinction (Weinstock et al., 2009). However, guanacos have more flexible social and foraging behaviors than vicuñas, which may have been important when the climate and environment changed during the Late Pleistocene and the Early Holocene. In deteriorated local conditions, the guanacos would have had the ability to migrate seasonally in large groups (Weinstock et al., 2009). These data may indicate that while

guanacos survived the transition Late Pleistocene/Early Holocene, its population densities could have been low during this period.

It is proposed that during the Early Holocene the human diet was generalized and included a wide diversity of resources. At that time, extinct mammals were available. According to Gutiérrez and Martínez (2008), 51 genera were registered in the Pampean region for the Late Pleistocene/Early Holocene, and 16 of these were extinct taxa, while six of them showed evidence of human butchery (Gutiérrez and Martínez, 2008: 61). In this sense, some of these animals were part of the diet of hunter–gatherers in the Pampean region, where the large mammals survived until at least *ca.* 7500 years BP (Politis and Gutiérrez, 1998; Gutiérrez and Martínez, 2008; Politis and Messineo, 2008; Gutiérrez et al., 2010). From that period, Pampean groups explored alternatives to replace these resources, which were no longer available. In addition, if the hypothesis stated here that camelid populations presented low densities in the environment, subsistence strategies should have focused on a diversification in the diet. Other evidence supporting this assumption is the record of coastal sites with exploitation of otariids in the Interserrana area for this period (Bayón et al., 2012). Some of these samples are La Olla 1, 2, 3, and 4, dated to *ca.* 7920–6480 years BP (Blasi et al., 2013), Barrio Las Dunas (surface site), dated to *ca.* 6900 years BP (Bayón et al., 2012), and Alfar, dated to *ca.* 5700 years BP (Bonomo and León, 2010). Such settlements with an important use of South American sea lion and fur seal are not registered for later Holocene times (Bonomo et al., 2013).

Toward the second half of the Middle Holocene, diet focused on artiodactyls, strongly documented for Paso Mayor at *ca.* 4500 years BP (between *ca.* 5800 and 3800 years BP; Frontini, 2012). Isotopic values from samples of the Interserrana area support this trend. Results obtained by Politis et al. (2009) on human remains of the Arroyo Seco 2 site (55 km from the coast) indicate that the subsistence was primarily based on the consumption of terrestrial herbivores during the Early and the Middle Holocene (human remains dated between *ca.* 7800 to 6300 years BP). However, some individuals (mostly men) incorporated marine proteins into their diets, and one of them showed high values of these nutrients. Two individuals recovered in the Atlantic coast (Monte Hermoso 1 and 2, dated to *ca.* 6600 and 7800 years BP) also showed high values of marine proteins (Politis et al., 2009). On the contrary, isotopic data from the Late Holocene human remains (El Guanaco, Laguna Tres Reyes 1, and Túmulo de Malacara sites) indicate that the groups

of the Interserrana area had a continental diet (Barrientos, 1997; Bayón et al., 2004).

Specialization in guanaco hunting toward *ca.* 4500 years BP generated changes in hunter–gatherer strategies, which can be illustrated through the following examples. For the archaeological site Nutria Mansa 1 (dated to between *ca.* 2700 and 2900 years BP), Kaufmann (2009: 268) proposed that guanacos were hunted through the use of active traps, dependent on the landscape topography. In these places, people could have limited the animals escape by corralling them in corners formed by waterways, and could have killed them by throwing weapons, such as *bolas*. In the case of Calera site, it was suggested that the aggregation of bands would have allowed predation on social groups of male guanacos. These troops are composed of immature and mature non-territorial males and are usually bigger than familiar groups (6–167 individuals) (Franklin, 1983; Larrieu et al., 1985; Fritz, 1985; among others). Male groups are highly mobile and difficult to obtain, but the convergence of bands coming from different territories would have facilitated their location because hunter–gatherers possessed and exchanged information on faunal resources (Kaufmann and Álvarez, 2007: 756).

For the Final Late Holocene, there are some methodological limitations, such as low temporal resolution and scarcity of samples. However, available data indicate continuity in the strategies of resource exploitation in relation to previous periods, although one of the analyzed samples showed an increase in its diversity value. For the Tandilia Ranges, Quintana and Mazzanti (2001) proposed that the intensification process involved a change in the use, selection, and incorporation of small animals into subsistence, with shorter reproductive cycles and high birth rates (Quintana and Mazzanti, 2001). In this area, three taxa, which did not have earlier antecedents of anthropic use, were incorporated into the diet. These are the rodents *Cavia aperea* (brazilian guinea pig; 0.5–1.5 kg) and *Galea tixiensis* (extinct endemic species of yellow-toothed cavy; similar weight to *Cavia aperea*); and the reptile *Tupinambis* sp. (Tegu lizard; usually 3.5–4 kg) (Quintana et al., 2002; Quintana, 2005). For the Interserrana area, none of the samples corresponding to *ca.* 1000 years BP provided evidence of the exploitation of taxa as small as the mentioned rodents. The rest of the assemblages (Claromecó 1 and Paso Vanoli sites; Bonomo et al., 2008; Frontini, 2012) indicated a low diversity. Nevertheless, the three samples together showed a slight decrease in the AI in relation to the initial Late Holocene but in summary these lines of evidence do not confirm the expected characteristics for an intensification process, although this hypothesis may be modified when new sites are analyzed.

Conclusions

Taking into account the subsistence model proposed by Martínez and Gutiérrez (2004) for the Pampean region, data presented in this paper are consistent with the *generalized regional economy* observed for the Early Holocene. Nevertheless, although s*pecialized regional economies* occurred for the Middle Holocene, they were not established until this period was advanced, and they continued during the Initial Late Holocene, and probably the Final Late Holocene. As Martínez and Gutiérrez (2004) noted, although the *diversification and intensification of areal economies* was documented for different areas of the Pampean region, in the Interserrana area the repertoire of exploited animals remained similar to that of previous periods. Analyses performed on ungulate skeletal part profiles, fragmentation of guanaco bones, results of taxonomic richness, and diversity and artiodactyls indexes do not support the existence of an intensification process in the Interserrana area. Nevertheless, more samples are required to confirm this

information in the earliest periods, and to date the Late Holocene pattern is the most reliable one.

The case of Calera, defined as a site of aggregation and feasting, shows an intensification in the social relationships (Bender, 1981; Lourandos, 1983, 1985; Williams, 1987), along with an increase in complexity in the Pampean region (Berón and Politis, 1997; Barrientos, 2001; Politis and Madrid, 2001; Quintana and Mazzanti, 2001; Madrid et al., 2002; Loponte et al., 2006; Martínez, 2006; Politis and Barros, 2006; among others). However, changes in social organization, as well as the introduction of new technologies, were not accompanied by an increase in animal resource procurement in the Interserrana area. On the contrary, the subsistence strategies maintained continuity with the previous periods. In this sense, it is likely that there were no major demographic changes and if there were any, they did not lead to resource depression.

Finally, this paper exemplifies the importance of reconsidering the temporal periods into which the Holocene has traditionally been divided. While these categories have made it possible to generate valuable models of subsistence strategies, they have also obscured the variability and changes in short-term scales.

Acknowledgments

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