

Faunal Exploitation and Agricultural Transitions in the South American Agricultural Limit

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ABSTRACT The southern Mendoza Province of Argentina constitutes the southernmost limit of Andean agriculture in South America. Archaeofaunal assemblages from sites in this region show a pattern of changing taxonomic diversity concomitant with the first appearance of domesticated plants. This pattern is characterised by an increase in prey diversity before the appearance of the first cultigens and a decrease in diversity after their arrival. Furthermore, the animal taxa exploited when domesticated plants entered the diet indicate a focus on big game. The pattern observed in southern Mendoza is in accord with ethnographic and archaeological models generated by faunal research worldwide. Copyright © 2008 John Wiley & Sons, Ltd.

Key words: archaeofauna; Argentina; domestic plants; diversity index

Introduction

The origins and diffusion of domesticated plants is currently one of the most exciting topics in archaeology, as it represents the last major human adaptation around the world and remains incompletely understood (Cohen, 1977). At frontier zones, agriculturalists remained closely related to their hunter-gatherer neighbours, with whom they traded, interacted and, in some cases, upon whom they depended for survival (Simms, 1986; Headland & Reid, 1989; O'Shea, 1989; Layton *et al.*, 1991; Wills, 1992; Dolvkhonov, 1993; Winterhalder & Goland, 1997; Barlow, 2002). Historically, our understanding of the role of cultigens in both agricultural and hunter-gatherer societies in southern Mendoza has been

restricted to the distribution of domestic plant remains (Lagiglia, 1968, 1981, 1999; Gil, 1997–98, 2000, 2003) and, more recently, to stable isotope analyses (Novellino & Guichón, 1997–98; Gil, 2003). However, viewing plant and animal use in isolation may impede our understanding of human subsistence behaviour. Thus, another fertile source of evidence for the incorporation of domesticated plants into the diet is archaeofaunal data and changes in animal use through time (James, 1990).

The purpose of this paper is to assess the role of hunting during the transition from exclusively hunting and gathering economies to those incorporating domesticates in Mendoza Province, the southernmost limit of Andean agricultural expansion. This change in the subsistence pattern in southern Mendoza occurred through interactions between hunter-gatherers and farming societies between 2000 and 1000 years BP.

Southern Mendoza is composed of a wide range of environments, from mountainous areas

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in the west to semi-desert plains in the east, which diversity is reflected in the faunal and floral resources of these areas. Since the earliest documentation by the first Spaniards in the region, southern Mendoza has been considered the limit of Andean agriculture in South America (Bibar, 1966). Although aspects of the true extent of the agricultural economy are still debated (Gil, 1997–98, 2000, 2003), archaeological data support this idea (Lagiglia, 1968, 1978, 1981, 1999; Gil, 2000). In the 1960s, the earliest domestic plant remains, dating to between 2200 and 1900 years BP, were discovered at the Gruta del Indio site. Four genera of domestic plants were recovered from this archaeological context: *Phaseolus vulgaris* (common bean), *Zea mays* (corn or maize), *Chenopodium quinoa* (quinoa), and *Cucurbita* sp. The associated archaeological complex was named the Atuel II culture and largely defined by the practice of agriculture (Lagiglia, 1968, 1978, 1981, 1997a, 1999). Today, 17 sites with archaeological remains of cultigens have been excavated. Recent research has focused on the importance of *Zea mays* in the diet within the last 2000 years, and these results have been integrated with $\delta^{13}\text{C}$ analyses from different skeletal populations (Novellino & Guichón, 1997–98; Gil, 1997–98, 2000, 2003; Novellino *et al.*, 2004; Neme, 2007). This information has enriched the discussion, but several questions remain regarding the real significance of cultigens in the diet and the impact they had on pre-Columbian societies (Gil, 1997–98).

Gil (2003) identified two different periods of crop use in southern Mendoza and suggested that during the first period (*ca.* 2000 years BP), crops were not used for subsistence. During the second period (*ca.* 1000 years BP), cultigens were more prevalent than in the earlier deposits and clearly played a role in subsistence (Gil, 2000). Gil (2003) proposed that the Atuel II 'culture' was not as clearly an agricultural or horticultural society as previously accepted. Recent evidence suggests the need to consider the possibility that the Atuel II people were hunter-gatherer bands (Sloway & Lee, 1990; Layton, 2001) living adjacent to and interacting with their agricultural neighbours (Gil, 1997–98, 2000). Although limited, stable carbon isotope evidence suggests that *Zea mays* was never a staple resource for these groups

(Novellino & Guichón, 1997–98; Gil, 2003; Gil *et al.*, 2006), and that other crops were not quantitatively significant (Hernández *et al.*, 2001; Hernández, 2002).

Faunal exploitation and agricultural expansion

Optimal Foraging models can be used to predict aspects of human decision-making (Bettinger, 1991; Kaplan & Hill, 1992). Although numerous criticisms have been raised regarding the use of Optimal Foraging Theory in archaeology, these refer primarily to problems of oversimplification of human behaviour and determinism (Balme, 1983). We believe that the predictive power and the ability to generate testable hypotheses make Optimal Foraging Theory a powerful resource for modelling subsistence behaviour. Some archaeologists have applied Optimal Foraging Theory to the appearance of the first domesticates (Szuter & Bayham, 1989; Winterhalder & Goland, 1993, 1997; Barlow, 2002). As these authors demonstrate, the study of faunal exploitation is a good means of testing problems related to the adoption of agriculture, since several changes in animal resource use can occur during the transition as a means of reducing the risk associated with the introduction of lower-return resources (Szuter & Bayham, 1989; Cohen, 1989; James, 1990; Winterhalder & Goland, 1997). It is possible that the introduction of cultivated foods does not initially impact the existing subsistence strategy. On the contrary, these new foods can help to maintain the original foraging strategy (Wills, 1992). For this reason it is difficult to determine precisely the location and timing of the transition to agriculture.

Several ethnographic and archaeological studies suggest different archaeofaunal patterns related to the transition to agriculture and its attendant increase in sedentism, reduced caloric returns, and technological changes (Simms, 1986; Szuter & Bayham, 1989; Speth & Scott, 1989; O'Shea, 1989; Cohen, 1989; James, 1990; Layton *et al.*, 1991; Winterhalder & Goland, 1993, 1997; Barlow, 2002; Cannon, 2003). The most notable differences in the archaeofaunal record are reductions in the amount of large game in the

diet and an increase in the proportion of fractured bones. The reduction in large game is the result of increased sedentism and depletion of the local large game populations (Cohen, 1989). That is, when sedentism increases as a result of more dependence on domesticated plant resources, the diet becomes broader and foraging efficiency declines (Barlow, 2002). However, James (1990) supported the idea that this process reverses itself when the adoption of agriculture is complete. According to Optimal Foraging Theory, this is because game in the surrounding area is depleted and hunting parties are forced to move longer distances, such that hunters prefer bigger game with higher return rates (Szuter & Bayham, 1989; James, 1990).

The agricultural economy, especially during the initial stages, has been defined as a 'third option' (Cohen, 1989), with significantly lower caloric return than large game hunting. According to Optimal Foraging Theory, this implies that while large game is abundant, a population will prefer to continue hunting rather than adopt an economy based on plant cultivation (Cohen, 1989; Szuter & Bayham, 1989; Layton *et al.*, 1991; Grayson & Delpech, 1998; Barlow, 2002). Conversely, as several authors remark, broad-spectrum foragers' economies are characterised by a lower caloric return than those based on big game hunting and agriculture (Cohen, 1989; James, 1990; Layton *et al.*, 1991; Barlow, 2002). In addition, the level of risk may increase as a result of a decreased focus on large game hunting, which risk can then be reduced by incorporating domestic plants into the diet (James, 1990; Layton *et al.*, 1991). Indeed, as Layton *et al.* (1991) remarked, the adoption of agriculture is not a strict movement in one direction and farmers could have returned to a hunter-gatherer economy if environmental conditions became more favourable for that strategy. If this is the case, we would expect an increase in taxonomic diversity in archaeofaunal assemblages through time, especially prior to 2000 years BP when the first domestic plant remains appear together with more fractured bones in the same samples, the latter being the product of more intensive use of bone marrow.

In boundary areas between hunter-gatherers and agriculturalists, it is possible that all or nearly

all domestic plants at sites attributed to hunter-gatherers were acquired by exchange (Simms, 1986; Headland & Reid, 1989; Layton *et al.*, 1991; Spielman & Eder, 1994). We would expect the incorporation of domestic plants to have had a small impact in the hunter-gatherers' economy at first, causing few immediate changes in their economic organisation (Wills, 1992). Evidence of this transition would be difficult to identify archaeologically despite the presence of domestic plants at many sites. Using archaeofaunal assemblages, we can test the impact that domesticates produced in hunter-gatherer and farming societies.

Methods and materials

The study area

Southern Mendoza is located between 34° and 37° south latitude, bounded on the west by the Argentine-Chilean border in the Andean Cordillera. The region is considered an archaeological and ethnographic boundary area between north Patagonian hunter-gatherers and complex agricultural societies of the northwest (Lagiglia, 1974, 1977).

Three main rivers irrigate the landscape. From north to south, these are the Diamante, Atuel and Grande Rivers (Figure 1). Southern Mendoza Province is a semiarid environment where phytogeographical characteristics are transitional between Patagonia and the Monte Province (Capitanelli, 1972). The former is considered a grass steppe and the latter is a shrub-dominated landscape (Roig, 1972). Annual rainfall is between 200 and 300 mm, with temperatures ranging from -5°C to 35°C. To the west, the Andean Cordillera, with peaks in excess of 5000 m above sea-level, constitutes another variable environment with two seasons (summer and winter) and vertically-arranged vegetational zones (Roig, 1972). Generally, water is scarce and the main water resources are creeks, rivers and lagoons in the Andes, and rivers and springs outside the mountain areas. Palaeoclimatic data suggest that the environment has been similar to today's during the last 4000 years (Markgraf, 1983; D'Antoni, 1983; Zárate, 2002). The faunal

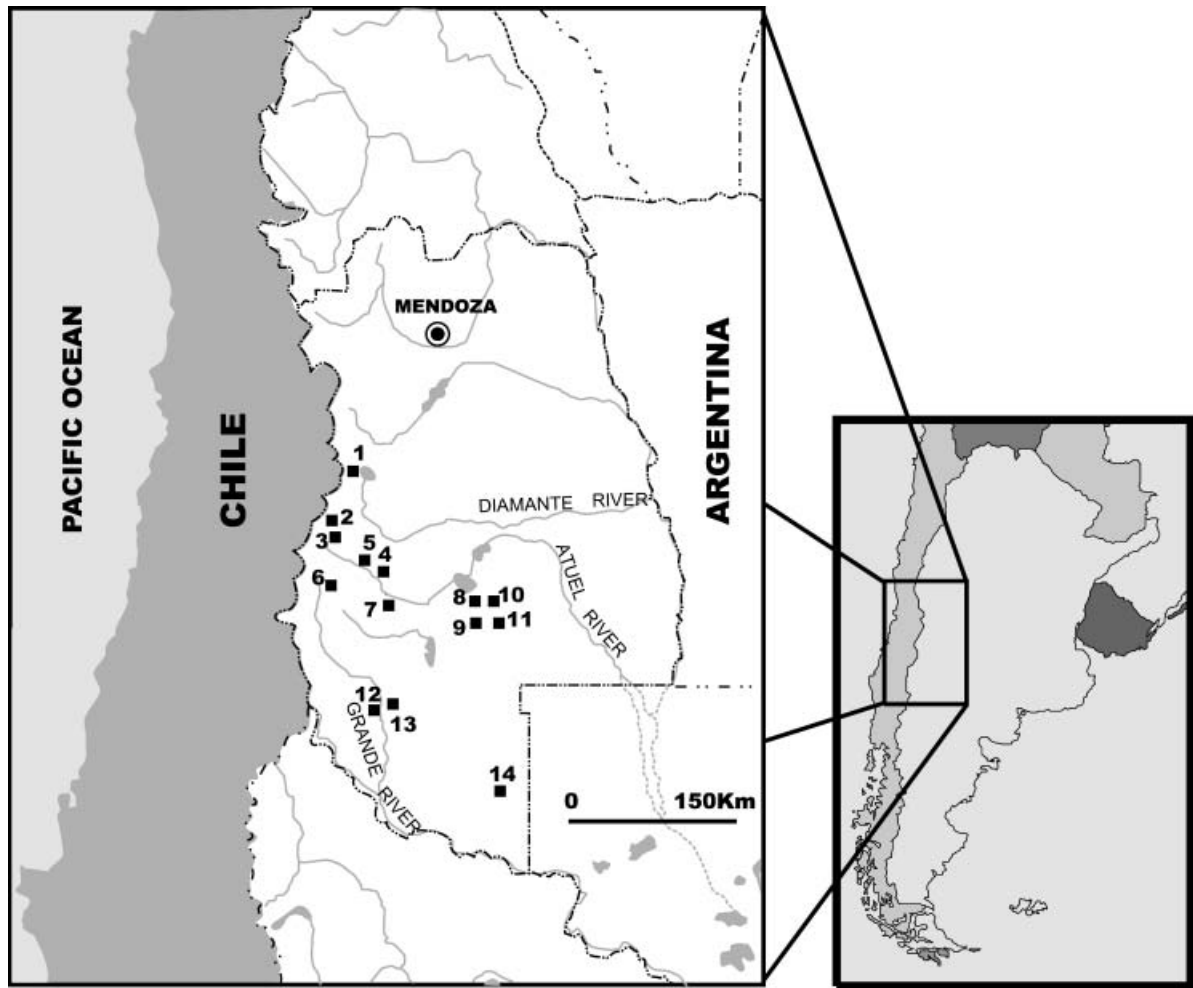


Figure 1. Map showing the southern Mendoza Province with the archaeological sites mentioned in the text. 1, Laguna El Diamante; 2, El Indígena; 3, Los Pequenes; 4, Arroyo Malo 3; 5, Arroyo Malo 1; 6, Cueva Arroyo Colorado; 7, Ojo de Agua; 8, Los Leones 3; 9, Puerto Ortubia 1; 10, Los Leones 5; 11, Agua de los Caballos; 12, Cueva de Luna; 13, Alero Puesto Carrasco; 14, La Peligrosa.

record agrees with this palaeoenvironmental reconstruction, indicating the presence of the same species throughout the period (Neme *et al.*, 1995, 1998; Gil & Neme, 1997). *Lama guanicoe* (guanaco) is the largest species present. It was the main dietary resource throughout this period in all regions. *Rhea americana* (greater Rhea), *Pterocnemia pennata* (lesser Rhea), *Lagidium viscacia* (vizzacha) and other small mammals are some of the most important faunal resources in the area.

Faunal diversity

As a means of assessing faunal diversity, we monitor diachronic variations in diet breadth. Estimations of diet breadth can be problematic, especially with respect to the calculation of a diversity index (Madsen, 1993). Significant variations in the index value can have considerable implications regarding human adaptations (Grayson & Delpech, 1998). As Grayson & Delpech (1998) remarked, the distributional

analysis of the assemblages through time, measured by the diversity index, could help to determine how often low-ranking resources were incorporated into the diet (Grayson & Delpech, 1998).

To investigate this, a sample of 20 archaeofaunal assemblages from 15 archaeological sites was included in this study. We include only assemblages from the last 4000 years BP. This chronological sequence was selected based on the main subsistence and settlement changes in the region that occurred during this period, and by this method we hope to monitor the changes in faunal exploitation in southern Mendoza (Durán, 1997; Gil, 1997–98, 2000; Neme, 2002, 2007). Table 1 displays all of the radiocarbon dates from each site. Many other sites with domestic plants were also dated, but faunal remains were not recovered from them or no data were published (for more information, see Gil, 1997–98).

The sites analysed here are located in a number of different environments throughout southern Mendoza, including caves, 'vegas' (fertile plains), creek and river margins and terraces. Site altitudes range from 700 m.a.s.l. on the plains to high altitude sites at 3600 m.a.s.l. There is also diversity in site function; many of these sites are base camps or multiple-activity sites and others are specific-activity sites, while some changed function through time. Despite their diversity, these sites show general regional tendencies in archaeofaunal exploitation. The total sample includes 42,185 bone specimens, 4291 of which were identified at the genus or family taxonomic level. In general, the predominant weathering level in the sample measured 1 or 2 on the Behrensmeier scale (Gil & Neme, 1997), increasing to 3 or 4 at high-altitude sites where environmental conditions are harsher (Neme, 2007). In Table 2 we present all the taxa from each assemblage.

Table 1. List of radiocarbon dates from the analysed sites

Site	¹⁴ C years BP	Lab code	Sample	Reference
El Indígena	980 ± 90	LP-430	Charcoal	Lagiglia <i>et al.</i> (1994a)
	840 ± 60	LP-611	Charcoal	Neme (2002)
	1170 ± 60	LP-573	Charcoal	Neme (2002)
	1470 ± 60	LP-562	Charcoal	Neme (2002)
	1045 ± 45	AA-26192	<i>Zea mays</i>	Neme (2002)
Los Peuquenes	360 ± 50	LP-1024	Charcoal	Neme (2002)
	280 ± 50	LP-1018	Charcoal	Neme (2002)
Arroyo Malo 3	2200 ± 50	LP-958	Charcoal	Neme (2002)
	3810 ± 105	LP-946	Charcoal	Neme (2002)
	3570 ± 40	NSRL-11721	Charcoal	Dieguez & Neme (2003)
Arroyo Malo 1	560 ± 65	LP-837	Charcoal	Neme (2002)
Cueva A° Colorado	770 ± 80	LP-447	Charcoal	Lagiglia <i>et al.</i> (1994b)
	1380 ± 70	LP-457	Charcoal	Lagiglia <i>et al.</i> (1994b)
	3190 ± 80	LP-472	Charcoal	Lagiglia <i>et al.</i> (1994b)
	1240 ± 70	LP-794	Charcoal	Gil (2000, 2002)
Agua de Los Caballos-1	740 ± 40	AA-26194	<i>Zea mays</i>	Gil (2000, 2002)
	640 ± 60	LP-1037	Charcoal	Gil (2000, 2002)
	365 ± 40	AA-26196	<i>Zea mays</i>	Gil (2000, 2002)
	250 ± 60	LP-962	Charcoal	Gil (2000, 2002)
	410 ± 80	LP-1145	Charcoal	Gil (2000, 2002)
Puesto Ortubia-1	600 ± 89	LP-1103	Charcoal	Gil (2000, 2002)
	650 ± 50	LP-928	Charcoal	Gil (2000, 2002)
	910 ± 40	AA-26197	<i>Zea mays</i>	Gil (2000, 2002)
	870 ± 70	LP-579	Charcoal	Gil (2000, 2002)
Los Leones-3	1930 ± 50	LP-1012	Charcoal	Gil (2000, 2002)
La Peligrosa	1200 ± 40	LP-921	Human bone	Novellino & Neme (1999)
Ojo de Agua 1	1490 ± 60	LP-321	Charcoal	Durán (2000)
Cueva de Luna	3830 ± 160	LP-341	Charcoal	Durán (2000)
Cañada de Cachi 01	2260 ± 120	LP-410	Charcoal	Durán (2000)
	3200 ± 120	LP-405	Charcoal	Durán (2000)
Alero Puesto Carrasco	470 ± 90	LP-424	Charcoal	Durán (2000)
	2090 ± 80	I-16638	Charcoal	Durán (2000)

Table 2. NISP of the taxa in each component from southern Mendoza sites

Taxa	CLA	CLB	CLC	PCA	PCB	CCB	CCC	ACA-1 ^a	PO-1	LC	LOLE-3	LOLE-5	LPE	AMA 3 (B)	AMA 3 (C)	AMA 1	OA	LP1	EI	LD
Bird indet.	35	27	15	13	3	1	1	1	—	5	1	—	14	1	—	—	1	—	2	12
Medium-sized bird	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11
Big bird	13	12	1	1	—	—	—	—	—	—	—	1	—	—	—	—	4	—	—	—
Small bird	1	1	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
Emberizidae	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Zenaidia auriculata</i>	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Eudromia elegans</i>	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Falconidae	1	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2
Passeriforme	4	1	—	18	—	—	—	—	—	1	—	—	—	—	—	—	3	1	—	1
Rheidae	1	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Pterocnemia pennata</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Rhea americana</i>	10	5	5	33	—	3	1	15(138)	5(186)	30(53)	10	—	—	2	2	—	143(139)	4(186)	—	10
Dasypodidae	7	1	—	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Euphratyni	12	10	1	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Chaetophractus</i> sp.	27	22	8	34	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Chaetophractus villosus</i>	2	—	—	—	—	—	—	2	—	—	1	2	—	—	—	—	—	—	—	3
<i>Zaedyus pichyi</i>	1	1	—	11	2	18	—	1	—	—	—	—	—	1	—	—	—	—	—	—
Carnivorous	1	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Conepatus</i> sp.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Felis concolor</i>	14	3	3	77	—	25	26	1	4	5	—	—	15	2	—	4	—	—	9	24
Artiodactyla	6	—	0	1	—	—	—	—	—	2	—	—	—	1	—	—	3	—	—	17
Caprininae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
<i>Ovis aries</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Camelidae	1	—	—	55	1	—	—	23	20	7	1	—	72	2	4	3	2	2	9	13
<i>Lama</i> sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	161
<i>Lama Guanicoe</i>	165	50	17	448	4	215	132	2	—	—	—	—	66	1	—	8	3	—	23	83
<i>Ozotocerus bezoarticus</i>	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Equus caballus</i>	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	19	—	—	—
<i>Equus/Bos</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—
<i>Lagidium viscacia</i>	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mammalia indet	244	155	22	423	1	105	30	14	6	5	—	1	72	5	7	4	17	6	4	254
Mammalia (big size)	33	44	9	349	4	93	79	42	83	4	1	—	91	5	5	6	24	31	6	62
Mammalia (med size)	—	2	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—
Mammalia (small size)	—	—	—	1	—	—	—	1	1	2	72	—	—	—	—	—	—	—	—	1
Micromammalia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Herbívoros	—	—	—	—	—	—	—	4	1	—	—	—	2	—	—	—	—	—	—	2
Chiroptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Reptilia	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Iguánide	—	—	—	—	—	—	—	—	2	3	—	—	—	—	—	—	—	—	—	—
Testudinidae	—	—	—	—	—	—	—	2	1	1	—	—	—	—	—	—	—	—	—	—
Mollusca	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—	—	—	—	—
Microvertebrates	X	X	X	X	X	X	X	X	X	X	X	—	X	X	X	—	—	X	—	—
Indeterminate	244	200	25	681	19	219	118	1878	6227	534	49	166	21561	351	691	3009	1155	616	151	14542
Total	829	535	106	2173	40	576	387	1995	6351	601	138	178	21913	374	709	3034	1382	660	204	15202

To gauge changes in taxonomic richness, we calculated the Shannon Diversity Index for each assemblage, before and after the introduction of domesticated plants in the region. One of the main problems that we encountered when comparing sites and assemblages from the same area or from very similar regions was that the samples were very similar in terms of diversity. To be truly useful, a diversity index must be capable of detecting minimal differences between localities or samples, especially between localities that are not very different. We chose the Shannon Index because it is one of the indices that is better able to discriminate between very similar samples (Magurran, 1987: 79–80). We explored the same tendencies using other diversity indices (Simpson Index, Margalef Index, and Menhinick Index) but the results were not significantly different.

$$\lambda = 1 / \sum_{i=1}^S (P_i) (\log_e P_i) \quad (1)$$

where λ = Diversity Index, P_i = proportion of individuals, and S = total number of species. To calculate the index we included only potentially exploitable taxa. In this sense we excluded Chiroptera, microvertebrates (including small iguanides), *Conepatus* sp. and *Mollusca*. Regarding the latter, we assume that this taxon was not consumed in southern Mendoza because the shells came to the site only as ornamental goods from the Pacific coast. Furthermore, microvertebrates, especially rodents, are not unambiguous indicators of human subsistence patterns. Taphonomic observations show that these were brought to the sites by owl and fox activity (Neme *et al.*, 2002). In Table 3 we present the diversity indices for each assemblage.

Several authors have demonstrated problems associated with sample size that can affect zooarchaeological interpretations (Grayson, 1989, 1991; Kintigh, 1989; Lyman, 1994; Azanza *et al.*, 1999). These authors observe that there is a high correlation between taxonomic diversity and sample size. For this reason, prior to discussing the significance of taxonomic diversity among the assemblages presented here, we must consider the potential effects of the size of our samples.

Figure 2 shows the correlation index between faunal diversity and sample size for each assemblage with a low correlation value (0.4959). However, two outliers appear in the graph; the one above the regression line is an assemblage from the El Indígena site and the one below the regression line is an assemblage from Arroyo Malo 1. The former is a sample that was only partially collected during fieldwork in 1972 (Lagiglia, 1997b); that is, only the more complete bones were retained, and for this reason we consider the collection inadequate for a discussion of problems related to sample size. The second outlier in Figure 2 is a small sample from an open-air site where the bones were subjected to considerable weathering and damage. Thus we excluded both outliers from the correlation analysis. Even excluding these two samples, however, the correlation was not very strong (0.6295), and for this reason we can assume that the diversity results are not highly affected by sample size. Therefore, we find it appropriate to use these data to discuss changes in taxonomic richness through time in the archaeofaunal samples from southern Mendoza.

Next, we compared patterns of taxonomic diversity through time in the archaeofaunal assemblages from southern Mendoza. From this correlation we excluded archaeological sites that lack radiocarbon dates or a secure chronological assignment (Los Leones-5), and sites or components where the number of identified specimens (NISP) of non-native, European animals is significant (Ojo de Agua and Cueva de Luna, component A). Figure 3 illustrates two main tendencies. Firstly, the assemblages dated to between 4000 to 1800 years BP show an increase in diversity values through time. Secondly, between 1800 to 300 years BP diversity decreased. The r^2 (statistical correlation) of the curve shown in Figure 3 is 0.31, which means that changes through time can explain only 31% of the variation represented in the curve. Because the correspondence with the curve is low, we use Student's *t*-test to determine whether the three different time periods (A: 4000–3000; B: 3000–1500; and C: 1500–200 years BP) are statistically different. The results indicate that period B is significantly different from periods A and C at a significance level of 95%, and that periods A and C are not significantly different from one

Table 3. Diversity Index values for each component from southern Mendoza sites

Taxa	CLA	CLB	CLC	PCA	PCB	CCB	CCC	ACA-1 (A)	PO-1	LC	LOLE-3	LOLE-5	LPE	AMA 3 (B)	AMA 3 (C)	OA	LP1	EI	L.D.
Indet. bird	—	—	—	—	-0.277	-0.016	-0.020	—	—	—	-0.050	—	-0.128	—	—	—	—	-0.123	—
Medium sized bird	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-0.067
Large bird	—	—	-0.054	—	—	—	—	—	—	—	—	-0.206	—	—	—	—	—	—	—
Small bird	—	—	—	-0.004	—	—	—	—	—	—	—	—	—	-0.212	—	—	—	—	—
Passeriforme	—	-0.016	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-0.017
Emberizidae	-0.193	—	—	—	—	—	—	-0.040	—	—	—	—	—	—	—	—	—	—	—
<i>Zenaidura macroura</i>	—	—	—	—	—	—	—	-0.040	—	—	—	—	—	—	—	—	—	—	—
<i>Eudromia elegans</i>	—	—	—	—	—	—	—	-0.040	—	—	—	—	—	—	—	—	—	—	—
Falconidae	-0.010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rheidae	—	-0.016	—	—	—	—	—	—	—	-0.062	—	—	—	—	—	—	-0.085	—	-0.009
<i>Pterocnemia</i>	-0.010	—	—	-0.012	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pennata</i>	—	—	—	—	—	—	—	—	-0.038	—	—	—	—	—	—	-0.057	—	—	—
<i>Rhea americana</i>	—	—	—	-0.153	—	—	—	—	-0.008	-0.359	—	—	—	-0.212	-0.244	-0.071	-0.217	—	-0.077
Dasyptidae	—	—	—	—	—	-0.040	-0.020	—	—	—	—	—	—	—	—	—	—	—	—
Euphratini	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetophraetax sp.	-0.180	-0.224	-0.244	-0.027	-0.277	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Chaetophraetax</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>villosus</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Zaedyus pichyi</i>	-0.193	—	—	-0.085	-0.223	—	—	-0.069	—	—	-0.050	-0.298	—	—	—	—	—	—	—
Carnivorous	—	-0.016	—	-0.035	—	-0.150	—	-0.040	—	—	—	—	—	-0.136	—	—	—	—	—
Conepatus sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Felis concolor</i>	-0.010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Artiodactyla	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Caprininae	-0.046	—	—	-0.004	—	—	—	—	—	-0.104	—	—	—	-0.136	—	—	—	—	-0.098
Camelidae	—	—	—	—	—	—	—	—	-0.294	-0.235	-0.050	—	—	-0.334	—	-0.057	-0.140	—	-0.367
<i>Lama guanicoe</i>	-0.356	-0.283	-0.327	-0.361	-0.315	-0.305	-0.349	-0.069	—	—	—	—	-0.313	-0.136	-0.364	-0.057	—	-0.3621	—
<i>Ozotoceros</i>	—	—	—	-0.008	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>bezoarticus</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Equus caballus</i>	-0.033	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-0.207	—	—	—
Equus/Bos	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Lagidium viscacia</i>	—	—	—	—	—	-0.029	—	—	—	—	—	—	—	—	—	—	—	—	—
Testudinidae	—	—	—	—	—	—	—	-0.069	-0.038	-0.062	—	—	—	—	—	—	—	—	—
Mollusca	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Indeterminate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	-1.036	-0.558	-0.625	-0.693	-1.094	-0.541	-0.390	-0.368	-0.726	-0.825	-0.150	-0.505	-0.441	-0.832	-0.578	-0.449	-0.444	-0.485	-0.658

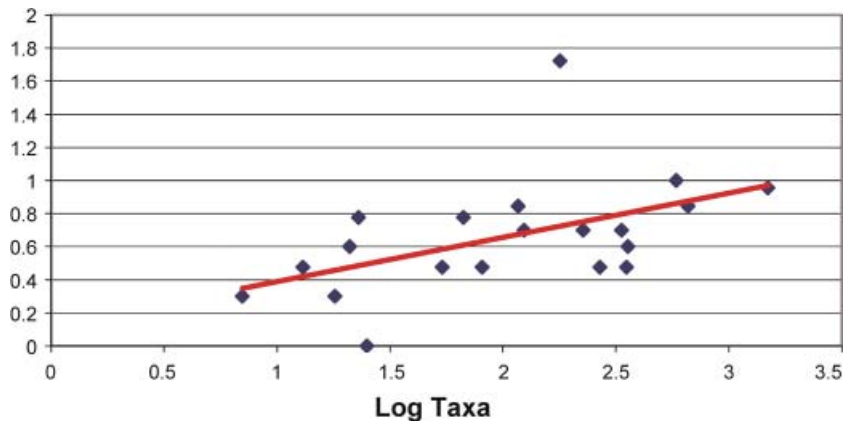


Figure 2. Correlation between sample size (log NISP) and Diversity Index (log Taxa) from southern Mendoza archaeofaunal assemblages. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

another at this level of probability. Finally, Figure 4 illustrates the average diversity of the three different periods (A, B and C) with the total dispersion of their assemblage values, in order to visualise changes in the diversity index through time.

Artiodactyla index

As discussed above, the diversity index indicates a curve tendency through time that allows us to recognise three different patterns. To test the relationship between the diversity index and a

subsistence strategy that focuses on big game, we calculated the Artiodactyla Index (Grayson, 1991; Cannon, 2003). In these calculations, we included the same assemblages used to calculate the diversity index with some alterations. For all of the Dasipodidae (including *Euphractyni*, *Zaedyus* sp. and *Chaetophractus* sp.), we used the number of elements represented by bones and excluded the dermic plates. In the assemblages that consist only of dermic plates, we counted as only one individual from each taxonomic category. The results are presented in Figure 5, which illustrates an inverse curve relative to the diversity curve presented in Figure 3. Two outlier assemblages

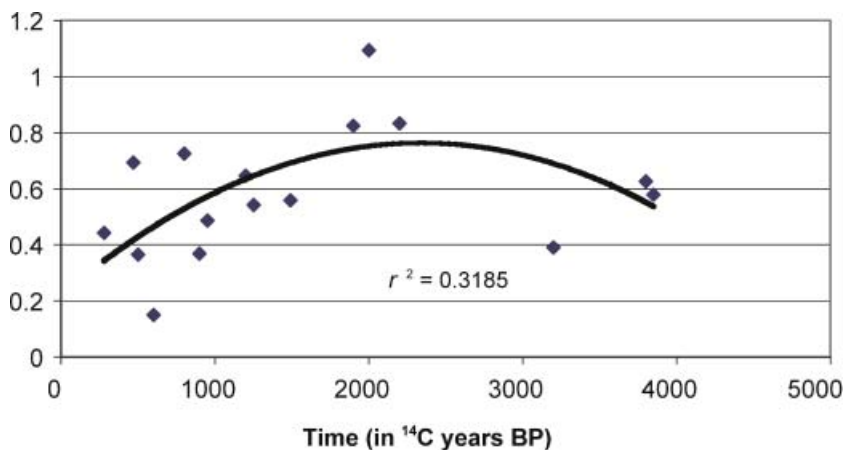


Figure 3. Faunal Diversity Index through time. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

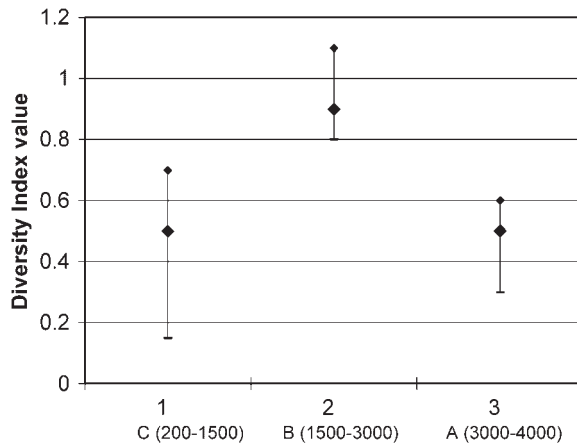


Figure 4. Average Diversity Index values and their dispersion by time period.

are evident in Figure 5 (Agua de los Caballos 1 and Los Leones 3). Both are from the more recent period and have the lowest values compared with other assemblages' distributions for that period (200 to 1500 years BP). The outlier assemblages are from two small rockshelters located in the

Monte desert. Grazing areas are limited at these locations, and thus the guanaco populations are smaller than those from the open prairies of Patagonia or 'Altoandina' deserts. For this reason, human populations at these sites could have focused on hunting other, smaller species that represent immediately local resources. A similar pattern was described by Szuter & Bayham (1989) in the American Southwest, regarding Hohokam societies relative to low-altitude sites. Their explanation for the higher taxonomic diversity observed at lower elevation sites is based on the proximity of farming groups' camps to places where they obtained prey. These camps were probably occupied for longer periods of time than higher-altitude sites because they were close to the crop fields. For this reason, big game in the area surrounding the camp was depleted, thereby necessitating a broadening of the diet to include smaller species. Conversely, the high-elevation sites far from the crop fields were smaller and occupied for shorter periods of time. People living at these camps had less impact on the resources surrounding camps, so that big game populations remained stable.

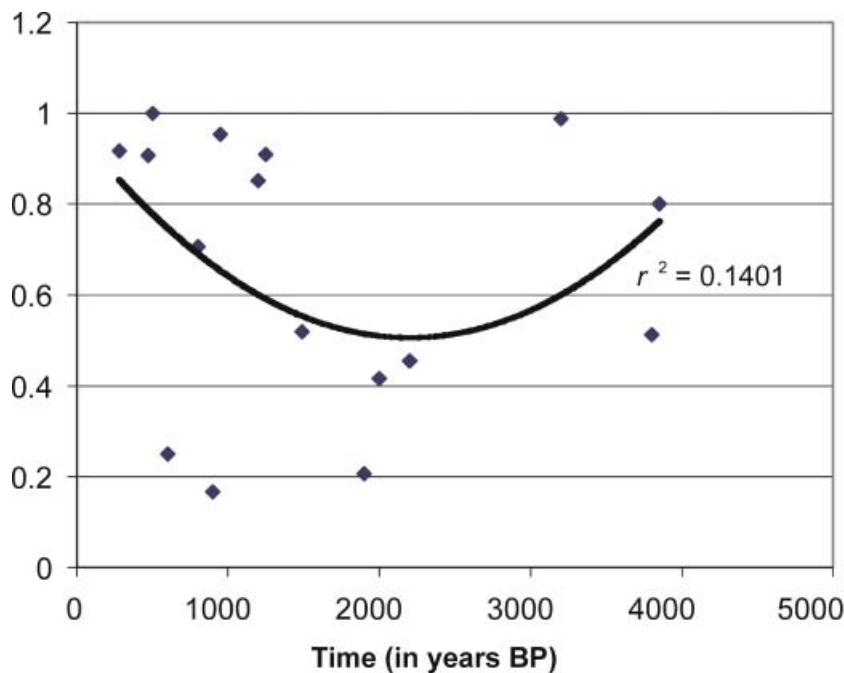


Figure 5. Artiodactyla Index through time from archaeofaunal assemblages. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Discussion

A resource intensification model was proposed for the last 2000 years in southern Mendoza Province, Argentina (Gil, 2000; Neme, 2002, 2007). This model indicates that high-risk regions with low primary productivity would be populated, and that there would be a decrease in large game hunting (*Lama guanicoe*) and an increase in plant processing. This process concluded with the adoption of agriculture between 2000 and 1000 years BP in some parts of the region. It is not easy to evaluate the real impact of agricultural adoption on a region-wide basis, because it is possible that the impact was not uniform, affecting some places more profoundly than others. Also, the influence of trade is not clear, and could have affected hunter-gatherer bands differently. None the less, hunting diversity increased (i.e. diet breadth increased) before approximately 1800 years BP, at which time it ceased to expand, concomitant with the appearance of the first agricultural products in the region (Lagiglia, 1968, 1978, 1981, 1999). The first cultigens appeared some centuries earlier (1900–2100 years BP), but it is possible that at that time they did not play a major role in human subsistence (Gil, 1997–98, 2003). Stable isotope data support this idea (Novellino & Guichon, 1997–98; Gil *et al.*, 2006). Apparently, these populations were taking more energy from their surrounding environment, increasing extraction costs to mitigate the decline of higher-ranking game due to overexploitation in the areas immediately surrounding the camps. Later, the adoption of domesticated plants allowed these groups to become more sedentary and to deplete the surrounding settlement area of game. This increased sedentism implies significant changes in resource use, especially regarding the diet, without abandoning the hunting strategy included in farming societies (Kent, 1989). As the distance between hunting locales and campsites increases, cost-benefit models predict an increased focus on big game hunting in order to improve return rates. This encouraged the population to decrease hunting diversity and to concentrate on larger species further away from their farming camps. Changes in the diversity index in each of the assemblages from southern Mendoza, as

shown in Figure 3, is consistent with James' (1990) models, discussed above. James hypothesised an increase in hunting diversity prior to agricultural adoption, and a decrease in species diversity after that. A similar pattern was observed by Cannon (2003) in Mimbres Valley, New Mexico, with variations in the relative proportion of *Artiodactyla* through time. James explained this variation as the result of big game depletion and changes in climatic conditions. We believe that the most recent decrease in hunting diversity in southern Mendoza can be explained in terms of Optimal Foraging Theory, which predicts that as the distance travelled by hunting parties increases, hunters will target only large game in order to derive the highest return.

Another prediction from James's model is an increase in the proportion of fractured bones as a result of bone marrow extraction. Until now, there have not been any studies on this phenomenon among sites in southern Mendoza, nor has there been any taphonomic research focusing on the problems related to differential preservation of bones in regional archaeological assemblages. Understanding taphonomic problems could be especially important for interpreting open-air and high-altitude sites, where bones are generally very poorly preserved. At such places, many bones tend to be broken. A simple comparison between total bone counts and counts corrected for taxonomic factors in each assemblage did not show any correlation with respect to pre- and post-domestic plant appearance in the archaeological record (i.e. before and after 2000 years BP).

Conclusions

Southern Mendoza Province is an excellent region to test hypotheses regarding the expansion of food producers in arid environments and models of interaction between food producers and hunter-gatherers, and to assess methods for recognising the archaeological signals of these two kinds of societies. In this sense, this paper demonstrates variations in human subsistence choices through time during the transition from hunting and gathering to farming at the southernmost South American limit of food production.

Variations in the species diversity index indicate a pattern that reflects changes in human decision-making in response to variation in big game availability, and could be correlated with increased sedentism, possibly caused by the introduction of domestic plants to the region. As mentioned above, the faunal pattern is coincident with changes observed in both isotopic and archaeobotanical data (Gil, 2003; Novellino *et al.*, 2004) and is consistent with predictions of diet breadth models (James, 1990; Layton *et al.*, 1991; Winterhalder & Goland, 1997).

A number of problems related to this study remain unresolved, including a lack of taphonomic information, the small number of the archaeofaunal samples available for analysis, the small size of the existing samples, and the functional variability of the sites considered. Nevertheless, we believe that this study has a number of strengths including a broad temporal span with good chronological references, the large size of the studied region and the inclusion of all its archaeological sites with archaeofaunal data. We consider this paper the initial step towards an understanding of early agricultural societies and faunal exploitation in the last South American farming frontier.

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