International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. **19**: 281–296 (2009)

(www.interscience.wiley.com) DOI: 10.1002/oa.1057

Isotopic Ecology and Human Palaeodiets in the Lower Basin of the Colorado River, Buenos Aires Province, Argentina

G. MARTÍNEZ,[a] **A. F. ZANGRANDO**[b*] AND **L. PRATES**[c]

[a] *CONICET, INCUAPA, Facultad de Ciencias Sociales, Universidad Nacional del Centro de la Provincia de Buenos Aires, Avda. del Valle 5737 (7400), Olavarría, Argentina*
[b] *CONICET, Asociación de Investigaciones Antropológicas, Universidad de Buenos Aires. Bartolomé Mitre 1131 7 "G" (1036), C.A. de Buenos Aires, Argentina*
[c] *CONICET, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque s/n (1900), La Plata, Argentina*

ABSTRACT Results of stable isotope analyses are presented for the study of human subsistence in the lower basin of the Colorado River, Buenos Aires province, Argentina. This paper provides the most current state of knowledge concerning isotopic research in the study area, which in turn sheds new light on such a significant region as the Pampa-Patagonia transitional zone, spatially related to the Atlantic coast. In addition, information from the middle basin of the Negro River is incorporated in the analysis and discussion. Both the construction of an isotopic ecology and the prehistoric human diets derived from δ^{13}C and δ^{15}N human isotope values for the area are explored. Stable isotope analysis of modern plants indicates a C_3 plant-based environment. Animal resources have δ^{13}C values that indicate a diet based mainly on C_3 products. Nevertheless, they have highly variable δ^{15}N values. Human isotopic values have the following mean values: $-18.8‰ \pm 1.08‰$ for $\delta^{13}C_{COL}$ ($n=25$), and $11.98‰ \pm 1.34‰$ for δ^{15}N ($n=25$). As a general trend, the results obtained from both C and N isotopic signals indicate a diet based on the consumption of protein provided by meat of terrestrial herbivores (e.g. artiodactyls) with the complement of fish. These results are in agreement with the data obtained from the zooarchaeological record for the Late Holocene. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: hunter-gatherers; eastern Pampean-Patagonian transition; Late Holocene; palaeodiet; carbon and nitrogen isotopes

Introduction

The lower Colorado River valley (Buenos Aires province) is located at the transition zone between the Pampas and Patagonia regions (Figure 1). A dry to semi-arid climate and an ecotonal environment characterise the area (see below). The analysis presented here is part of a recently developed project called 'Archaeological Research in the Lower Valley of the Rio Colorado, Buenos Aires District, Argentina'. The main objectives pursued by this project are to understand the adaptation and evolution of hunter-gatherer societies that inhabited the study area, as well as their population dynamics. Given the scarce archaeological knowledge available for the area until recently, different lines of research are being conducted in order to build a data-set

---

* Correspondence to: CONICET, Asociación de Investigaciones Antropológicas, Universidad de Buenos Aires, Bartolomé Mitre 1131 7 "G" (1036), C. A. de Buenos Aires, Argentina.
e-mail: panchozan@yahoo.com.ar

Received 13 October 2008
Accepted 28 October 2008

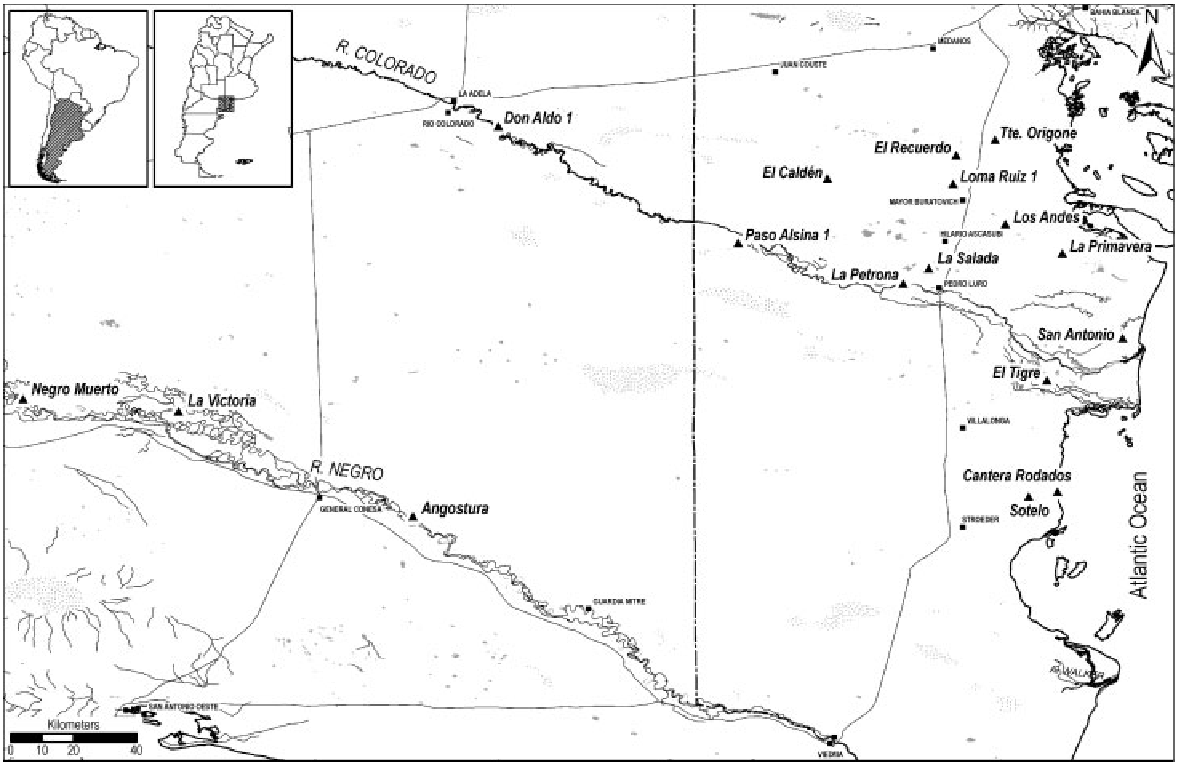

Figure 1. Lower basin of Colorado River and the middle basin of the Negro River (Argentina) showing locations of sites discussed in text.

that allows the discussion of these objectives. Along these lines, recent studies including analysis of radiocarbon chronology, subsistence, organisation of lithic technology, mobility and home ranges, settlement systems, human burials and funerary practices have been conducted (Martínez & Figuerero Torres, 2000; Armentano, 2004a,b, 2008; Bayón *et al.*, 2004; Martínez, 2004, 2008; Martínez *et al.*, 2005, 2006a,b, 2007; Prates *et al.*, 2006; Stoessel, 2006, 2007). As previously mentioned, data from the middle basin of the Negro River are also included (Prates, 2007) (see Figure 1). Up to this point in both areas, current archaeological evidence has systematically recorded dates to the Late Holocene (*ca.* 3000–250 years BP).

Given this background, the objective of this paper is to provide information about a new line of research in this area: stable isotope analysis of human remains and resources. In this sense, the first results on human diets and isotopic ecology are presented and discussed here. This information contributes to the understanding of hunter-gatherer subsistence. Thus, the results of stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) carried out on human bones from archeological sites, as well as those obtained from vegetal and animal species ($\delta^{13}C_{COL}$ samples, both archaeological and modern ones) used as potential food during prehistoric times, are discussed. The isotopic results obtained are utilised to characterise human palaeodiets and to identify dietary patterns in relation to the consumption of terrestrial (e.g. vegetal, animal) and aquatic resources (e.g. fish). Finally, regional and temporal variations in diet and subsistence and issues related to mobility and use of the landscape are explored.

Archaeological evidence for human subsistence in the lower Colorado River basin

Zooarchaeological studies of Late Holocene assemblages (*ca.* 3000–250 years BP) have revealed a general pattern of subsistence based

DOI: 10.1002/oa

on the exploitation of mainly guanaco (*Lama guanicoe*), complemented by deer (*Ozotoceros bezoarticus*), Rhea (*Rhea americana*), and plant resources. Nevertheless, some changes in subsistence occurred in this general pattern towards the final Late Holocene (*ca*. 1000–250 years BP). While the acquisition and consumption of artiodactyls, like guanaco, continued to provide the most important part of subsistence, the economic importance of armadillo and marine and freshwater fish resources became greater. We record a dietary diversification indicating the exploitation of small and medium-sized prey from different ecological settings (Martínez *et al*., 2006c; Stoessel, 2006, 2007; Martínez, 2008). Thus, zooarchaeological assemblages show a significant increase in taxonomic diversity towards the end of the Late Holocene, and a wide temporal and spatial variability in the exploitation of different kinds of resources. As an example, the sites near the Atlantic coast are located in an area covered by the ancient delta of the Colorado River (e.g. between *ca*. 4–20 km distance), and show an increase in the number of marine and freshwater fish species. The changes in subsistence previously mentioned are in tune with the increment, and standardised designs of milling artifacts also indicate that plant exploitation could have intensified (Stoessel, 2007; Armentano, 2008; Martínez, 2008).

To sum up, zooarchaeological data indicate a complementary use of coastal resources, while the base of the subsistence relied upon terrestrial foods. On this basis, a more systematic integration of the coastal areas regarding subsistence, spatial organisation and mobility can be recognised in the study area for the final phase of the Late Holocene (*ca*. 1000–250 years BP).

Palaeodietary reconstructions using stable isotope analysis on human remains is a well-established technique applied in archaeology (e.g. Tauber, 1981; Sealy & van der Merwe, 1986; Lee-Thorp *et al*. 1989; Ambrose, 1993; Pate, 1994; Schoeninger, 1995; Ambrose *et al*. 1997). In contrast to traditional methods of subsistence reconstructions, such as zooarchaeological studies, stable isotope analysis provides a direct quantitative measure of past human diet. One of the aims of this paper is to test to what extent the subsistence pattern already described is in agreement with the palaeodietary model presented here by using stable isotopes. Therefore, this paper is concerned only with the stable isotope values of the protein component of human diet.

Ecological conditions

The Colorado River runs from the Andes to the Atlantic Ocean crossing through various environments. One of the main features in the study area is the ancient delta, which is associated with an extremely complex system of palaeochannels. The lower basin of the Colorado River represents the remnant of an ancient delta that extended from Bahia Blanca, in the north, to San Blas in the south (see Melo *et al*., 2003). Its mouth is defined as an 'estuario de frente de delta', affected by tide dynamics and salt intrusion (Piccolo & Perillo, 1997); it has also been defined as a shallow delta or a platform delta. The ancient delta covered an area of *ca*. 900 km^2, with a front along the Atlantic coast of *ca*. 40 km and covering a distance of 90 km from the mouth inland (Cappannini & Lores, 1966). The form of the coast is the product of a strong erosive process, which occurred during the marine ingression and a further regression that took place during *ca*. 6900–400 years BP (Piccolo & Perillo, 1997; see also Weiler, 1983; Spalletti & Isla, 2003). Codignotto & Marcomini (1993) indicate that the area of the delta has reached 12 km towards the interior during the last 6000 years (see Figure 1). Within the deltaic plain, aeolian corridors originated by the river are documented (Spalletti & Isla, 2003). The geomorphology of the coastal area is characterised by low and extended beaches (Piccolo & Perillo, 1997).

The study area is enclosed in the so-called 'Arid Diagonal', in the southernmost part of South America (Abraham de Vázquez *et al*., 2000). It is characterised by a warm and dry steppe arid climate, with a mean annual rainfall of 466 mm, while temperatures vary from 22.2°C in January to 7.5°C in July (Sánchez *et al*., 1998). The dominant vegetation belongs to the 'Distrito del Caldén' and 'Provincia del Espinal', although vegetal communities of the 'Provincia del Monte' are also recorded in the area (Morello, 1958). Thus, the arid to semi-arid sandy area presents a shrub steppe, an open vegetal formation composed of xeric short trees mixed with hardy and scarce herbaceous grasses. The area is dominated by C_3 flora (e.g. *Geoffroea decorticants* or 'chañar', *Prosopis* sp. or 'algarrobo', and *Condalia microphilla* sp. or 'Piquillín'), although C_4 species are also present in a subordinated proportion (Villamil & Scoffield, 2003). From a zoogeographical point of view, the area is located in the 'Subregión Patagónica', 'Distrito Patagónico', where the following species are recorded: *Lama guanicoe* (wild camelid called 'guanaco'), *Chaetophractus villosus* ('peludo', armadillo), *Zaedyus pichiy* ('piche', armadillo), *Dolichotis patagonum* (patagonic hare or 'mara'), *Lagostomus maximus* ('vizcacha', large rodent), and *Rhea americana* ('ñandú', greater Rhea), among others (Cabrera & Yepes, 1960).

Between the mouths of the Colorado and Negro rivers, ictiogeographical studies indicate that there is an overlap in the distribution of fish species from the Austral and Brasílica subregions (Almirón *et al.*, 1997). According to the information on the distribution of plants, in addition to the data on animals and fish provided above, the study area is characterised as a region of environmental variability that coincides with the ecotone characteristic of the eastern Pampean-Patagonian transitional zone (Morello, 1958; Páez *et al.*, 2001; Pezzola *et al.*, 2003; Schäbitz, 2003; Villamil & Scoffield, 2003).

Palaeoclimatic studies (Schäbitz, 1994, 2003) indicate that during the last 6000 years climatic conditions would have been continually arid and semi-arid, although towards the final part of the Late Holocene an expansion of some lakes was recorded (see Schäbitz, 1994; Figures 4 & 5). The presence of a buried 'A' soil horizon in the study area, which indicates a higher effective humidity and landscape stability, is in agreement with this (Martínez, 2008).

Towards the construction of the stable isotopic ecology: carbon and nitrogen isotope values of plants and faunal remains

Carbon and nitrogen isotope measurements were performed on plant and faunal samples, both modern and archaeological, at the INGEIS (CONICET, Argentina) and at the Cornell Isotope Laboratory (Cornell University, US). Modern samples provided most of the carbon isotopic information for plants. The selection of the taxa potentially consumed by humans was based on travellers' chronicles and ethnographical accounts that mention their consumption by hunter-gatherer societies. Faunal bones were chosen from radiocarbon-dated archaeological sites. The archaeological samples of food resources come from the sites Loma Ruiz 1 (*ca*. 1900–1600 years BP), El Tigre (*ca*. 500 years BP), and San Antonio 1 (*ca*. 1000–400 years BP), in the lower basin of the Colorado River, and from Negro Muerto (*ca*. 480–400 years BP) and Angostura 1 (*ca*. 900–400 years BP) sites, in the middle basin of the Negro River (Prates, 2007; Martínez, 2008).

Stable carbon isotopic analysis was undertaken on 18 plant genera (15 C_3 specimens, two C_4 specimens and one CAM specimen; Table 1). Twenty-one modern and one archaeological sample were analysed, and all of the $\delta^{13}C$ values were consistent with the expected photosynthetic pathways. The mean of $\delta^{13}C$ for modern values is $-24.37‰ \pm 4.30‰$, which must be corrected by approximately $+1.5‰$ to account for changes in atmospheric CO_2 from pre-industrial times (Friedli *et al.*, 1986). The isotopic values of the archaeological sample of *Prosopis* sp. are $-25.61‰$ for $\delta^{13}C$ and 5.56‰ for $\delta^{15}N$. If we correct the modern measurements, and if the archaeological sample is included in the same group, the overall mean of $\delta^{13}C$ in plants is about $-23‰$.

The isotopic values of terrestrial fauna are shown in Table 2. The $\delta^{13}C$ values of guanaco (*Lama guanicoe*) present a mean of $-21.04‰ \pm 3.10‰$, indicating mainly C_3 plant diets. Nevertheless, the two results from Loma Ruiz 1 have higher values that reflect C_4 vegetal consumption.

The ñandú (*Rhea americana*) samples present a mean of $-21.08‰ \pm 0.02‰$, also indicating a diet based on C_3 vegetation. Values of other terrestrial resources, like deer (*Ozotoceros bezoarticus*; $-22.12‰$) and armadillo (*Zaedyus pichiy*; $-20.08‰$), also show C_3 diets. The overall mean of $\delta^{13}C$ for terrestrial herbivores is $-21.59‰ \pm 2.28‰$.

DOI: 10.1002/oa

Table 1. $\delta^{13}C$ values for modern plants sampled for the construction of the isotopic ecology

Taxa	Common name	Age	Lab code	$\delta^{13}C$
Portulaca sp.	Verdolaga	Modern	AIE 16353	−13.3
Malvella leprosa	Amapolita	Modern	AIE 16354	−26.8
Prosopis alpataco	Alpataco	Modern	AIE 16355	−24.6
Oxalis lasiopetala	Macachín	Modern	AIE 16356	−27.2
Condalia microphylla	Piquillin	Modern	AIE 16357	−26.7
Geoffroea decorticans	Chañar	Modern	AIE 16358	−25.6
Bromus brevis	Cebadilla pampeana	Modern	AIE 16359	−25.6
Schinus fasciculatus	Molle	Modern	AIE 16360	−26.5
Habranthus jamesonii	Cebolla de la zorra	Modern	AIE 16361	−26.8
Geoffroea decorticans	Chañar	Modern	AIE 16362	−26.1
Ephedra ochreata	Solupe	Modern	AIE 16363	−23.3
Ephedra triada	Pico de gallo	Modern	AIE 16364	−23.7
Ephedra sp.	Pico de gallo	Modern	AIE 16365	−25.1
Distichis scoparia	Pasto salado	Modern	AIE 16366	−16.4
Hoffmanseggia grauca	Algarrobilla fina	Modern	AIE 16367	−26.6
Oxalis lasiopetala	Macachín	Modern	AIE 16368	−29.0
Prosopis sp.	Algarrobo	Modern	AIE 16369	−27.4
Arjona tuberosa	Macachín/chaquil	Modern	AIE 16370	−26.8
Opuntia sp.	Cactus	Modern	AIE 16371	−13.4
Stipa sp.	Flechilla	Modern	AIE 16372	−25.4
Limonium brasilense	Guaycurí	Modern	AIE 16373	−25.5
Prosopis sp.	Alpataco/algarrobo	Archaeological	AQ 26316	−25.6

The $\delta^{15}N$ values for the ungulates (*Lama guanicoe* and *Ozotoceros bezoarticus*) and flightless birds (*Rhea americana*) are comparable to those observed for similar resources in central-northern Patagonia, where herbivores are included in a range of *ca*. 4–8‰ (Gómez Otero, 2007). The mean of $\delta^{15}N$ values for terrestrial herbivores is 5.89‰ ± 1.57‰.

The armadillo $\delta^{15}N$ value (10.8‰) is higher than those for the herbivores, which may indicate differences in trophic levels because of their omnivorous diet. Due to particularities of the feeding behaviour and diet of the armadillos, the isotopic values are quite different from those of the ungulates and flightless birds. In fact, insects, worms, small vertebrates, vegetables and moss

Table 2. $\delta^{13}C$ and $\delta^{15}N$ values for terrestrial fauna from the lower basin of the Colorado River and Northern-Central Patagonia

Taxa	Common name	$\delta^{13}C$	$\delta^{15}N$	Reference
Lama guanicoe	Guanaco	−19.90		This paper
Lama guanicoe	Guanaco	−17.80		This paper
Lama guanicoe	Guanaco	−16.20		This paper
Lama guanicoe	Guanaco	−23.90		This paper
Lama guanicoe	Guanaco	−22.80		This paper
Lama guanicoe	Guanaco	−23.90		This paper
Lama guanicoe	Guanaco	−22.80		This paper
Lama guanicoe	Guanaco	−21.34	8.25	Gómez Otero (2007)
Lama guanicoe	Guanaco	−21.43	5.22	Gómez Otero (2007)
Rhea americana	ñandú	−21.10		This paper
Rhea americana	ñandú	−21.06		This paper
Rhea americana	ñandú	−22.25	4.36	This paper
Pterocnemia pennata	Choique	−24.93	7.19	Gómez Otero (2007)
Pterocnemia pennata	Choique	−22.33	4.38	Gómez Otero (2007)
Ozotoceros bezoarticus	Venado	−22.12	5.97	This paper
Zaedyus pichiy	Piche	−20.08	10.80	This paper

DOI: 10.1002/oa

Table 3. δ^{13}C and δ^{15}N values of fish resources from the lower basin of the Colorado River and Northern-Central Patagonia

Taxa	Common name	Site	δ^{13}C	δ^{15}N	References
Percichthys sp.	Perch	El Tigre site	−23.10		This paper
Percichthys sp.	Perch	Lower valley Chubut River	−23.17	8.19	Gómez Otero (2007)
Genidens barbus	Sea catfish	San Antonio 1 site	−20.13	13.70	This paper
Micropogonia furnieri	White croaker	San Antonio 1 site	−18.96	9.32	This paper

comprise the diet of *Zaedyus pichiy*, and it also scavenges upon animals. Given the fact that the feeding behaviour of the armadillos is quite different from that of ungulates and flightless birds, their isotopic values are treated separately, and they will not be taken into account for calculating δ^{15}N and δ^{13}C mean values.

The analysis of fish remains showed lower δ^{13}C values than for terrestrial herbivores (Table 3). This pattern has also been noted in other regions of the world, especially in freshwater systems (Dufour *et al.*, 1999; Katzenberg & Weber, 1999). The samples of perch (*Percichthys* sp.) have quite negative values when compared with mixohaline species (*Genidens barbus* and *Micropogonia furneri*) which inhabit the mouth and estuary of the Colorado River. These isotopic signals are associated with high δ^{15}N values (*ca.* 9‰ to 14‰), which are significantly higher than those obtained from terrestrial herbivores. The δ^{13}C and δ^{15}N means in fish resources are 21.49‰ ± 2.12‰ and 10.40‰ ± 2.91‰, respectively.

In sum, the analysis of botanical and faunal samples from the lower basin of the Colorado River provides a reference isotopic data-set against which the human δ^{13}C and δ^{15}N values can be compared. Figure 2 shows the δ^{13}C and δ^{15}N means calculated from plants, terrestrial and fish resources. Terrestrial and fish resources are clearly different from one another. The stable carbon isotopic analysis undertaken on botanical

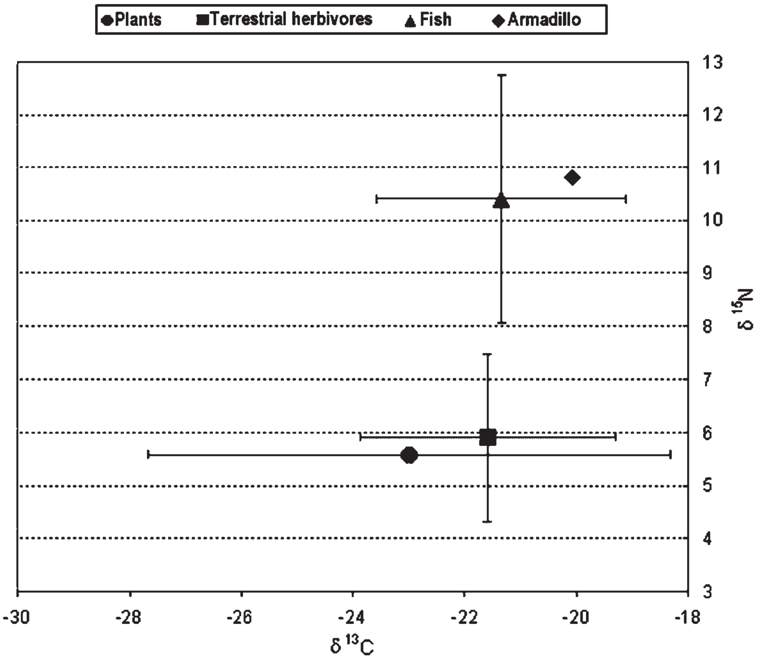

Figure 2. Correlation of δ^{13}C and δ^{15}N mean values of plants and fauna remains.

samples confirmed a C_3 ecosystem, which is also coherent with the herbivore values. The samples of terrestrial herbivores yielded a δ^{15}N mean value of 5.89‰, while in fish the isotopic signal presents a relative enrichment (10.40‰). To sum up, the obtained isotopic ecology indicates three main potential supplies of food resources: fish, terrestrial herbivores and vegetation. In addition, the difference between terrestrial herbivores and fish isotopic values becomes greater when the armadillos are taking separately. Given these figures, and due to the distinct isotopic signatures indicated by the isotopic ecology, it is possible to discriminate the human consumption of a particular set of food staples, from either terrestrial and/or aquatic environments.

Mortuary contexts, chronology and materials for human analysis

Human bone remains for isotopic analysis were chosen from five mortuary contexts: four sites from the lower basin of the Colorado River (La Primavera, Don Aldo 1, La Petrona and Paso Alsina 1) and one site from the middle basin of the Negro River (La Victoria 5). Next, we provide a brief description of these mortuary contexts as well as the radiocarbon ages with their respective δ^{13}C values (Table 4).

The oldest record of human occupation in the lower Colorado River valley comes from the La Primavera site. The radiocarbon data were obtained from three different individuals from two excavated burials (one primary and one with unknown modality) and from human remains recovered at the site surface. The human bones represented at the site reach a minimum number of individuals (MNI) of 5. The site is assigned to a multiple activities base-camp where human inhumations were also performed. Radiocarbon data provide a chronological span of *ca*. 2900–2700 years BP (Bayón *et al*., 2004; Martínez, 2008).

A primary burial of *ca*. 800 years BP was recovered at the Don Aldo 1 site which is interpreted as the result of residential occupations, where domestic activities and at least one

Table 4. Radiocarbon chronology of the human burials with their isotopic values

Site-burial	^{14}C	Code	δ^{13}C (‰)	References
PRI-1	2800 ± 60	GX-28772	−18.9	Bayón *et al*. (2004)
PRI-2	2882 ± 49	AA-70561	−16.1	Martínez (2008)
PRI-3	2728 ± 48	AA-70560	−18.9	Martínez (2008)
LV5-1	868 ± 48	AA-62796	−20.9	Prates *et al*. (2007)
LV5-2	928 ± 39	AA-70563	−18.5	Prates *et al*. (2007)
DA1	780 ± 45	Ua-22560	−18.6	Prates *et al*. (2006)
LP1-1	352 ± 51	AA-43126	−17.3	Martínez (2004)
LP1-2	314 ± 45	AA-43127	−25.0	Martínez (2004)
LP2-1	481 ± 37	AA-43124	−17.4	Martínez (2004)
LP2-2	770 ± 49	AA-43125	−17.4	Martínez (2004)
LP3-1	411 ± 39	AA-43122	−17.9	Martínez (2004)
LP3-2	462 ± 39	AA-43123	−17.4	Martínez (2004)
LP4-1	248 ± 39	AA-70564	−18.2	Martínez (2008)
PA1.E1	497 ± 43	AA-63958	−19.5	Martínez *et al*. (2007)
PA1.E2.1	452 ± 35	AA-59695	−18.9	Martínez *et al*. (2007)
PA1.E2.2	471 ± 43	AA-63959	−17.9	Martínez *et al*. (2007)
PA1.E3	570 ± 44	AA-63960	−20.0	Martínez *et al*. (2007)
PA1.E4	516 ± 44	AA-63961	−17.9	Martínez *et al*. (2007)
PA1.E5.1	465 ± 43	AA-63962	−20.9	Martínez *et al*. (2007)
PA1.E5.2	448 ± 43	AA-63963	−19.4	Martínez *et al*. (2007)
PA1.E6	476 ± 43	AA-63964	−18.8	Martínez *et al*. (2007)
PA1.E7	485 ± 43	AA-63965	−19.7	Martínez *et al*. (2007)
PA1.E8	465 ± 41	AA-70562	−18.4	Martínez *et al*. (2007)
PA1.E9	446 ± 42	AA-63966	−18.1	Martínez *et al*. (2007)
PA1. E10A	504 ± 34	AA-59696	−18.9	Martínez *et al*. (2007)
PA1. E10B	483 ± 34	AA-59694	−18.4	Martínez *et al*. (2007)

PRI, La primavera; LV5, La Victoria 5; DA1, Don Aldo 1; LP, La Petrona; PA1, Paso Alsina 1.

DOI: 10.1002/oa

inhumation event were carried out (Prates *et al.*, 2006). Two primary burials with a similar age (*ca*. 900–850 years BP) were found at the La Victoria 5 site, in the middle basin of the Negro River, where only activities related to burial practices are inferred (Prates *et al.*, 2007).

Primary and secondary human burial modalities were excavated at the La Petrona site. Two incomplete but articulated primary burials and two secondary ones (a single and a multiple individual burial) were recovered from a *ca*. 25 m^2 area in a sand dune. The estimated MNI = 6. The radiocarbon chronology of the burials spans from *ca*. 500–250 years BP. The artefacts recovered from the surface of the dune suggest that the site was a multipurpose base camp where human burial also took place (Martínez & Figuerero Torres, 2000; Martínez, 2008).

Paso Alsina 1 site is a bounded funerary structure (6 m^2; see Figure 3) located on a dune, where ten secondary burials were excavated. Thirteen radiocarbon dates from the human bones range from *ca*. 570 to 450 years BP, although the weighted average yielded an age of 483 ± 20 years BP. On the basis of the crania alone, an MNI of 55 is recognised. Bones are painted in red and the presence of cut-marks indicates that some bodies were disarticulated and defleshed before secondary burials were performed. Every secondary burial shows an internal repetitive pattern in both the location and association of specific bone specimens, as well as in the frequency of axial and appendicular skeletal parts. The patterned burial orientation and the contiguous and/or overlapped arrangement of the secondary burials follow a spatial arrangement produced by an intentional mortuary practice. The conjunction of this evidence with the chronological data indicates that the inhumation of the secondary burials corresponds to a single event (Martínez *et al.*, 2006a, 2007; Martínez, 2008).

Human isotopic ratios

Human isotopic ratio measurements were made at the NSF-Arizona AMS Facility (University of Arizona, US) and the Cornell Isotope Laboratory

Figure 3. Secondary burials at Paso Alsina 1 site.

DOI: 10.1002/oa

Table 5. Results of stable isotope analyses (δ^{13}C and δ^{15}N) and chemical indicators (C yield [%] and C/N) for human specimens by mortuary contexts

Site-burial	Lab. code	C yield (%)	C/N	δ^{13}C (‰)	δ^{15}N (‰)
PRI-1	CCNR-107221			−18.9	11.7
PRI-2	AQ-26305	19.2	3.80	−16.2	12.1
PRI-3	AQ-26304	35.2	3.28	−19.4	11.0
LV5-1	AQ-26309	15.8	4.28	−19.5	9.6
LV5-2	AQ-26311	27.7	3.55	−19.5	7.8
DA1	Ua-22560			−19.3	11.8
LP1-1	CCNR-107222			−16.7	11.1
LP1-2	AQ-26303	32.9	3.34	−19.3	12.2
LP2	CCNR-107223			−17.6	11.8
LP3	CCNR-107224			−17.7	10.3
LP4	AQ-26302	34.4	3.21	−19.6	12.9
PA1.E1	AA-63958	39.9	3.22	−19.6	12.4
PA1.E2.1	AA-59695			−18.9	11.9
PA1.E2.2	AA-63959	37.1	3.23	−17.9	13.0
PA1.E3	AA-63960	35.9	3.19	−20.0	13.4
PA1.E4	AA-63961	32.8	3.28	−17.9	13.1
PA1.E5.1	AQ-26307	30.0	3.08	−19.9	13.8
	AA-63962	41.5	3.23	−20.9	14.1
PA1.E5.2	AA-63963	42.1	3.24	−19.4	11.5
PA1.E6	AA-63964	42.1	3.24	−18.8	12.7
PA1.E7	AA-63965	39.4	3.21	−19.7	11.8
PA1.E8	AQ-26306	14.1	3.91	−18.0	11.6
PA1.E9	AA-63966	42.6	3.19	−18.1	12.1
PA1. E10A	AA-59696			−18.9	12.8
PA1. E10B	AA-59694			−18.4	13.0

(Cornell University, US). The values of chemical indicators and elemental data, together with the isotopic results of δ^{13}C and δ^{15}N, are shown in Table 5. The C:N ratios calculated for 18 samples are between 3.08 and 4.28. Only three samples (PRI-2, LV5-1 and PA1-E8) fall outside of the expected range for good collagen preservation: 2.9–3.6 (DeNiro, 1985). As a general trend, the results show that human samples have a good preservation state and there is no significant difference between the different mortuary contexts.

The δ^{13}C values of uncontaminated samples exhibit a narrow range (−20.9‰ to −16.7‰) that indicates a diet based mainly upon terrestrial C_3 resources. Nevertheless, the human δ^{15}N values show more widespread and enriched values than δ^{13}C (7.8‰ to 14.1‰). This general isotopic profile indicates that individuals consumed a diverse amount of animal protein, from terrestrial to aquatic settings (see below).

The individuals most highly enriched in ^{15}N have values up to 6–8‰ higher than the mean value for herbivores (5.89‰). Such elevated δ^{15}N values are difficult to explain with a single trophic level increase, if terrestrial herbivores are used as the reference food source. Every sample considered here comes from adult individuals and, consequently, the ^{15}N enrichment could not be attributable to a weaning factor in any case (Katzenberg *et al.*, 1996; Schurr, 1998). Since fish present significantly higher δ^{15}N values than terrestrial resources, human δ^{15}N values fall within the range observed for individuals that regularly consume these aquatic animals (Figure 4). In addition, the cases with high values also suggest that fish may have provided a considerable part of human diets, combined to varying degrees with proteins derived from C_3 terrestrial resources. The zooarchaeological evidence (Martínez *et al.*, 2005, 2006c) also demonstrates fish consumption. The composition of the ichthyo-archaeological record indicates that a combination of marine (mixohaline species) and riverine fish resources could explain the isotopic signatures of human samples.

There are no important variations in the human diet between mortuary contexts (Tables 6 & 7). The range of mean δ^{13}C values for humans is from

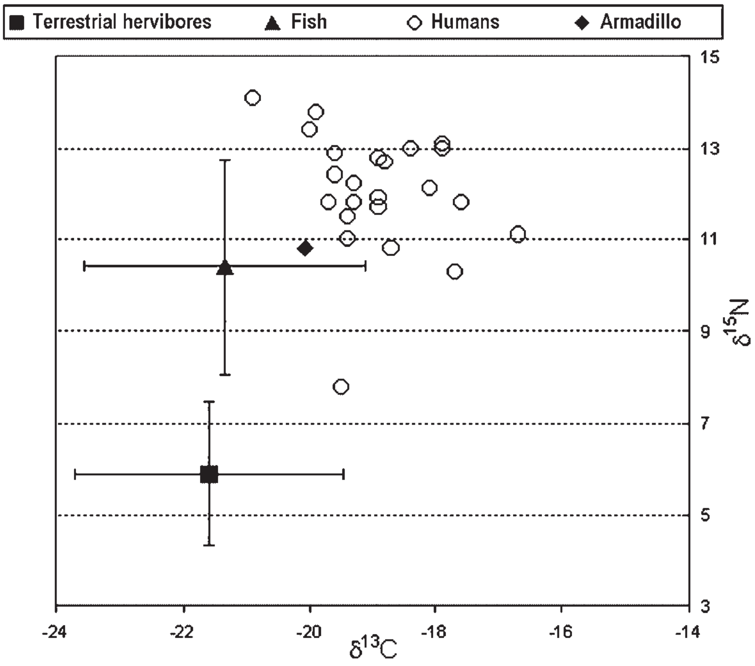

Figure 4. Carbon and nitrogen stable isotope ratios for protein from human and non-human faunal bone.

−19.15‰ at the La Primavera site to −18.18‰ at the La Petrona site, and there is no statistically significant difference between the $\delta^{13}C$ means of all samples at a 95% confidence level. Nitrogen isotope values are elevated in all groups, although this signature is highest at Paso Alsina 1, where there is a mean value of 12.62‰. The comparison of $\delta^{15}N$ means shows a significant difference between Paso Alsina 1 and the other mortuary contexts. Nevertheless, Figure 5 shows that there is a small variation among isotopic signatures at two scales: between single individuals and between mortuary contexts. According to the last level, the La Primavera and La Petrona average values show the extremes of a continuum where the Paso Alsina 1 average is included.

With the only exception of La Victoria 5, the differences between the nitrogen values of humans (discriminated by mortuary contexts) and terrestrial resources span from 4.8‰ to 6.2‰. As seen above, these differences are greater than the value commonly considered (3–4‰) between

Table 6. Statistical data for human specimens by mortuary contexts

Site	*n*	Isotope ratio	Average	Maximum	Minimum	Standard deviation
La Petrona	5	$^{13}C/^{12}C$	−18.18	−16.70	−19.60	1.22
		$^{15}N/^{14}N$	11.66	12.90	10.30	1.00
La Primavera	2	$^{13}C/^{12}C$	−19.15	−18.90	−19.40	0.35
		$^{15}N/^{14}N$	11.35	11.70	11.00	0.49
Paso Alsina 1	12	$^{13}C/^{12}C$	−18.95	−17.90	−20.00	0.76
		$^{15}N/^{14}N$	12.62	13.80	11.50	0.69
Don Aldo 1	1	$^{13}C/^{12}C$	−19.30			
		$^{15}N/^{14}N$	11.80			
La Victoria 5	1	$^{13}C/^{12}C$	−19.50			
		$^{15}N/^{14}N$	7.80			

DOI: 10.1002/oa

Table 7. Comparison of $\delta^{13}C$ and $\delta^{15}N$ means (Student's *t*-test)

	Isotope ratio	Paso Alsina 1	La Petrona
La Primavera	$^{13}C/^{12}C$	$t = -0.339$ ($p = 0.740$)	$t = 1.045$ ($p = 0.343$)
	$^{15}N/^{14}N$	$t = -2.450$ ($p = 0.030$)	$t = 0.401$ ($p = 0.704$)
La Petrona	$^{13}C/^{12}C$	$t = 1.603$ ($p = 0.064$)	
	$^{15}N/^{14}N$	$t = -2.298$ ($p = 0.036$)	

two successive trophic levels (Schoeninger & DeNiro, 1984), even taking into consideration values of ^{15}N-enrichment reaching up to 5‰, as indicated by other authors (Bocherens & Drucker, 2003; Drucker & Bocherens, 2004). Since the mortuary contexts are dispersed all over the lower basin of the Colorado River (Figure 1), a concomitant consumption of fish resources is suggested. The zooarchaeological evidence also suggests a more systematic exploitation of fish that could have been limited to specific places along the coast, such as the mouth of the main fluvial streams, the ancient delta and associated palaeochannels, and the estuary (Martínez *et al.*, 2006c). It is unlikely that the aquatic isotopic signatures recorded for human remains found on inland sites are the result of the transport of quantities of fish from the coast, given that no fish remains were found at these sites. We suggest it is more probable that these isotopic signatures indicate that human groups moved along a maritime coast–inland axis, and that people accomplished part of their annual activities at the coastal fringe (e.g. ancient delta and estuary of the Colorado River). A large diversity of resources were available in this part of the landscape, mainly several fish species. Nevertheless, this interpretation is relative and can only be supported on the assumption that there is a relatively direct spatial relationship between the place where the isotopic signal was produced and the place where the people were finally buried (Barberena *et al.*, 2006). Complex funerary practices are detected for the final Late Holocene, as shown by the presence of secondary burials and places assigned exclusively to burial practices

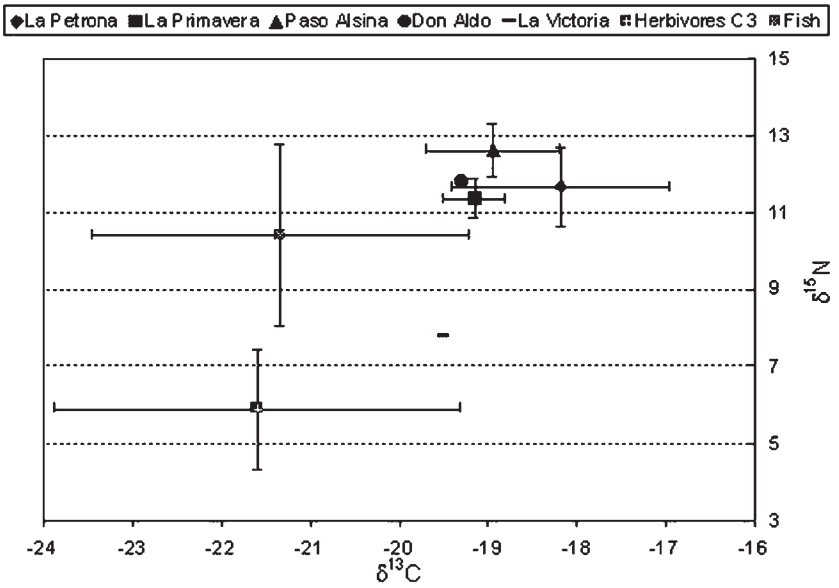

Figure 5. Carbon and nitrogen stable isotope ratios for protein from faunal bones and human values, plotted by mortuary contexts.

(e.g. Paso Alsina 1, MNI: 55). This funerary behaviour involved exhuming corpses of people who had had their primary burial in specific sectors of the landscape. After recovery, human bones were finally arranged in secondary burials at a different spot (Martínez, 2008).

Discussion

Isotopic studies in different settings of eastern north-central Patagonia are at different stages of development. Nevertheless, the results obtained are very useful in order to illustrate and understand the case presented here. Recent archaeological research carried out in the Río Negro province coastal area has yielded a record of primary and secondary human burials (Favier Dubois *et al.*, 2007). The chronology and human isotopic values suggest dietary differences between individuals dated at *ca*. 3000–2000 years BP and those coming from a later context, at *ca*. 1200 years BP. The greatest dependence on marine resources is suggested for the earlier period (see Table 3 in Favier Dubois *et al.*, 2007: 364; Borella, 2007). Despite the fact that the sample is still small, $\delta^{13}C$ values show an important maritime signature.

Gómez Otero *et al.* (2000) and Gómez Otero (2007) performed studies on the isotopic ecology of the central-northern Patagonian coast and the lower valley of the Chubut River area. They also produced isotopic information for human samples covering the period of 6000–200 years BP. The $\delta^{13}C$ (both inorganic and organic fractions) and $\delta^{15}N$ values for human samples indicate mixed, terrestrial and marine diets. Among these, those that show a clear marine signature were recorded near the Atlantic coast. For the period 1000–400 years BP, isotopic values for some individuals clearly indicate the consumption of marine resources (e.g. pinnipeds; Gómez Otero, 2007). To sum up, a significant number of samples (see Tables 6 & 7 in Gómez Otero, 2007) present a strong signature of marine species consumption.

Despite the differences in sample size, the two case studies mentioned above reveal that marine foods have had a more important dietary role during the Late Holocene than in the case of the Colorado River (see Tables 4 & 5). The following factors can be used to explain these differences. Firstly, the archaeological record of the study area indicates that neither cetaceans nor pinnipeds were exploited. These animals are almost absent or not readily available at the Atlantic shoreline where the Colorado River flows into the Atlantic Ocean. Carrara (1952) only identified two breeding rockeries (Punta Lobos and Banco Culebras) located at the Trinidad and Los Riachos islands, respectively. The absence of pinnipeds surrounding the coasts of the ancient delta of the Colorado River could have occurred due to the lack of some basic behavioural and physiological requirements of these species such as rockeries, cliffs, and shade (Borella, 2007). The geomorphology of the area characterised by scarce relief, and low and extended beaches (Piccolo & Perillo, 1997) is in accordance with the proposition that this section of the coast is not suitable for the establishment of pinniped rockeries.

Secondly, the archaeological record shows that the consumption of both marine and freshwater fish was concentrated in specific spots of the coastal landscape (Martínez *et al.*, 2006c). This is the case in the area of the ancient delta and its palaeochannels linked with the estuary of the river. Estuaries have a high biological productivity, which is even more important than in the adjacent river and the ocean. The freshwater–marine transitions have properties such as protected water bodies that collect and concentrate nutrients and biological species. In these estuary ecosystems, the contribution of terrestrial elements and detritus is important. Mixohaline fish such as *Micropogonia furnieri* and *Genidens barbus* are present in the archaeological record linked with the coastline. *Micropogonia furnieri* is well adapted to estuaries given its tolerance of low salinity environments, and its presence is recorded at freshwater drainage systems located several kilometres from the coast. In addition, *Genidens barbus* are introduced into fluvial systems (Perillo, 1995; Piccolo & Perillo, 1997; Acha *et al.*, 2004).

The $\delta^{13}C$ and $\delta^{15}N$ values vary throughout different ecosystems at the base of the food webs. The analysis of ^{13}C enrichment for consumers indicates that systematic differences exist in the pathways of organic carbon flow among aquatic ecosystems. Foraging across isotopically distinct

DOI: 10.1002/oa

habitat boundaries will obscure isotopic relationships between consumers and food sources can be expected to be greater in freshwater environments and estuaries than in coastal zones, and may be almost absent in the open ocean (France & Peters, 1997: 1257). If, due to different environmental pressures (e.g. temperature, salinity changes), a fish changes to alternative carbon sources, a concomitant change in their isotopic composition is expected (Kline *et al.*, 1998: 1495). Thus, given the habitat, behaviour and physiology of these marine fish, the isotopic signature could experience a depletion, which in turn would produce an isotopic signal in human consumers that does not necessarily indicate a stronger marine input.

To sum up, even though marine fish consumption by humans could have a noteworthy role in prehistoric diet, the isotopic signature is not indicative of an intense marine dietary input as occurred southwards in Patagonia. The explanation relies on the above-mentioned reasons combined with the ecological and geomorphological conditions of the study area.

Conclusions

Among the different lines of archaeological evidence developed since the beginning (2001) of the project in the lower basin of the Colorado River, stable isotope studies became an important tool for investigating ancient environments, palaeodiet, mobility, settlement and use of landscape. The importance of constructing an isotopic ecology for this region needs to be stressed. The results obtained from modern and archaeological animal and plant remains are an indispensable device for understanding human isotopic values, which in turn lead to an accurate reconstruction of human palaeodiets.

The isotopic data obtained for the area for the Late Holocene is interpreted as reflecting the consumption of protein provided by meat of terrestrial herbivores (e.g. artiodactyls) complemented by fish. This conclusion is in agreement with the zooarchaeological record. In this sense, the faunal evidence for the final Late Holocene (*ca*. 1000–500 BP) indicates the incorporation of small mammals and fish in the diet (Martínez *et al.*, 2006c; Stoessel, 2006, 2007; Prates, 2007). This pattern shows that while the acquisition and consumption of ungulates (i.e. guanaco and deer) was part of a patterned strategy of prey exploitation, the economic importance of armadillos and freshwater and marine fish resources increased through this period.

As was previously pointed out, there are no statistically significant differences between the $\delta^{13}C$ means of samples from the different sites, such as La Primavera, La Petrona and Paso Alsina 1. Given that the chronology of these sites ranges from *ca*. 3000 to 250 years BP, similar patterns in subsistence and dietary behaviour throughout the Late Holocene can be supported. Nevertheless, the chronological gap produced by the absence of human burials during the period *ca*. 2700–900 years BP may influence this interpretation. Clearly, a more complete record is needed to address this issue.

Regarding mobility, settlement and use of landscape, complementary evidence from stable isotopes and funerary practices indicates that the individuals moved between the inland and the Atlantic coast with some regularity, probably annually. The resolution of the local archaeological evidence is not complete enough to develop a thorough analysis of the type and frequency of mobility. Nevertheless, evidence of the management and movement of human corpses throughout the landscape, the complexity of settlements ranging from sites of inhumation (e.g. Paso Alsina 1) to reoccupied base camps (e.g. La Petrona) where human inhumation was also carried out, could indicate the employment of a planned strategy of covering the landscape for the final Late Holocene.

The archaeological knowledge of the lower basin of the Colorado River is enriched by the development of different lines of research. For this reason, stable isotope analyses of resources and humans were carried out, and the first database and interpretations of prehistoric human diets for the area were presented in this paper. Furthermore, these data were integrated with the subsistence patterns derived from zooarchaeological studies, and the location and particularities of human burials, which allowed for the discussion of issues related to mobility and use of landscape by Late Holocene hunter-gatherers.

Acknowledgements

This research was supported by FUNDACIÓN ANTORCHAS (Grant No. 4022/2.; 2002-2005) and a CONICET project named 'Paleoecología isotópica del área ecotonal Pampa-Patagonia (Pcia. de Buenos Aires)' (PIP No. 6147/05). The authors thank Dr Rosemary Scoffield (Department of Biology, Universidad Nacional del Sur, Bahía Blanca) who kindly guided the determination of the plants analysed for the isotopic ecology. We are very grateful to Heidi Luchsinger who corrected the English draft version. Thanks to T. Jull (NSF-Arizona AMS Facility, University of Arizona, US) for his help and assistance with the radiocarbon dating. The authors also thank the INCUAPA (Facultad de Ciencias Sociales, Universidad Nacional del Centro de la Provincia de Buenos Aires). Special thanks to editors of this volume, who invited us to participate.

References

Abraham de Vázquez E, Garleff K, Liebricht H, Reigaráz A, Schäbitz F, Squeo F, Stingl H, Veit H, Villagrán C. 2000. Geomorphology and paleoecology of the arid diagonal in southern South America. *Geodesy, Geomorphology and Soil Science. Sonderheft ZAG*: 55–61.

Acha E, Mianzan H, Guerrero R, Favero M, Bava J. 2004. Marine fronts at the continental shelves of austral South America. *Journal of Marine Systems* **44**: 83–105.

Almirón A, Azpelicueta M, Casciotta J, López Carzola A. 1997. Ichthyogeographic boundary between the Brazilian and Austral subregions in South America. *Argentina. Biogeographica* **73**: 23–30.

Ambrose SH. 1993. Isotopic analysis of paleodiets: Methodological and interpretative considerations. In *Investigations of Ancient Human Tissue, Chemical Analysis in Anthropology*, Sandford MK (ed.). Gordon and Breach Science Publishers: Pennsylvania; 59–130.

Ambrose S, Butler B, Hanson D, Hunter-Anderson R, Krueger H. 1997. Stable isotopic analysis of human diet in the Marianas Archipelago, Western Pacific. *American Journal of Physical Anthropology* **104**: 343–361.

Armentano G. 2004a. *Organización de la Tecnología Lítica en el valle inferior del río Colorado (Pdos. de Patagones y Villarino, Pcia. de Buenos Aires)*. Unpublished BA dissertation, Facultad de Ciencias Sociales, UNICEN, Olavarría.

Armentano G. 2004b. Observaciones Preliminares acerca de la Organización Tecnológica del valle inferior del río Colorado: Sitio Caldén Guazú-Medano 1-Sector Este. In *Aproximaciones Arqueológicas Pampeanas: Teorías, Métodos y Casos de Aplicación Contemporáneos*, Martínez G, Gutiérrez M, Curtoni R, Berón M, Madrid P (eds). FACSO-UNCPBA: Olavarría; 227–246.

Armentano G. 2008. Arqueología del curso inferior del río Colorado: organización de la tecnología lítica. In *INCUAPA 10 años. Perspectivas contemporáneas en la Arqueología Pampeana y Norpatagónica*, Politis G (ed.). Serie Monográfica del INCUAPA 5. FACSO-UNCPBA: Olavarría; in press.

Barberena R, Tessone A, Zangrando AF. 2006. Arqueología e isótopos estables en Patagonia: historia y perspectivas. *'Taller Arqueología e Isótopos Estables en el Sur de Sudamérica. Discusión e Integración de Resultados.' Notas del Museo de Historia Natural de San Rafael* **60**: 16.

Bayón C, Martínez G, Armentano G, Scabuzzo C. 2004. Arqueología del valle inferior del río Colorado: el sitio La Primavera. *Intersecciones en Antropología* **5**: 39–53.

Bocherens H, Drucker D. 2003. Trophic level isotopic enrichments for carbon and nitrogen in collagen: case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology* **13**: 46–53.

Borella F. 2007. ¿Dónde están los lobos en la costa atlántica de Norpatagonia? explorando vías para resolver el registro arqueofaunístico. *Werken* **9**: 97–114.

Cabrera A, Yepes J. 1960. *Mamíferos Sudamericanos*. EDIAR: Buenos Aires.

Cappannini D, Lores R. 1966. *Los suelos del valle inferior del Río Colorado*. Colección Suelos, N° 1. INTA: Buenos Aires.

Carrara I. 1952. *Lobos marinos, pingüinos y guaneras del litoral marítimo e islas adyacentes de la República Argentina*. Ministerio de Educación, Facultad de Ciencias Veterinarias (Publicación especial). UNLP: La Plata.

Codignotto J, Marcomini S. 1993. Argentina deltas morphology. In *Coastal Zone '93, Proceedings of the Eighth Symposium on Coastal and Ocean Management*, Magoon O, Wilson W, Converse H, Tobin L (eds). ASCE (3): New Orleans; 323–336.

DOI: 10.1002/oa

DeNiro RJ. 1985. Post-mortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* **317**: 806–809.

Drucker D, Bocherens H. 2004. Carbon and nitrogen stable isotopes as tracers of change in diet breadth during the Middle and Upper Palaeolithic in Europe. *International Journal of Osteoarchaeology* **14**: 162–177.

Dufour E, Bocherens H, Mariotti A. 1999. Palaeodietary implications of isotopic variability in Eurasian lacustrine fish. *Journal of Archaeological Science* **26**: 617–627.

Favier Dubois C, García Guraieb S, Borella F, Mariano C. 2007. Primeros avances acerca del registro bioarqueológico de la costa rionegrina. In *Resúmenes ampliados del XVI Congreso Nacional de Arqueología Argentina*, Vol. III. Facultad de Humanidades y Ciencias Sociales: Universidad Nacional de Jujuy: San Salvador de Jujuy; 359–364.

France R, Peters R. 1997. Ecosystem differences in the trophic enrichment of ^{13}C in aquatic foods webs. *Canadian Journal of Fisheries and Aquatic Sciences* **54**: 1255–1258.

Friedli H, Lotscher H, Oeschger H, Siegenthaler U, Stauffer B. 1986. Ice core record of the ^{13}C/^{12}C ratio of atmospheric CO_2 in the past two centuries. *Nature* **324**: 237–238.

Gómez Otero J. 2007. Isótopos estables, dieta y uso del espacio en la costa atlántica centro-septentrional y el valle inferior del río Chubut (Patagonia Argentina). In *Arqueología de Fuego-Patagonia. Levantando piedras, desenterrando huesos . . . y develando arcanos*, Morello F, Martinic M, Prieto A, Bahamonde G (eds). Ediciones CEQUA: Punta Arenas; 151–161.

Gómez Otero J, Belardi JB, Tykot R, Grammer S. 2000. Dieta y poblaciones humanas en la costa norte del Chubut (Patagonia Argentina). In *Desde el país de los Gigantes. Perspectivas arqueológicas en Patagonia*. Universidad Nacional de la Patagonia Austral: Río Gallegos; 109–122.

Katzenberg MA, Herring DA, Saunders SR. 1996. Weaning and infant mortality: evaluating the skeletal evidence. *Yearbook of Physical Anthropology* **39**: 177–199.

Katzenberg MA, Weber A. 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. *Journal of Archaeological Science* **16**: 319–329.

Kline T, Wilson W, Goering J. 1998. Natural isotopic indicators of fish migration at Prudhoe Bay, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences* **55**: 1494–1502.

Lee-Thorp JA, Sealy JC, van der Merwe NJ. 1989. Stable carbon isotope ratio differences between bone collagen and bone apatite, and their relationship to diet. *Journal of Archaeological Science* **16**: 585–599.

Martínez G. 2004. Resultados preliminares de las investigaciones arqueológicas realizadas en el curso inferior del río Colorado (Pdos. de Villarino y Patagones; Pcia. de Buenos Aires). In *Aproximaciones Arqueológicas Pampeanas: Teorías, Métodos y Casos de Aplicación Contemporáneos*, Martínez G, Gutiérrez M, Curtoni R, Berón M, Madrid P (eds). FACSO, UNCPBA: Olavarría; 275–292.

Martínez G. 2008. Arqueología del curso inferior del río Colorado: estado actual del conocimiento. En *INCUAPA 10 años*, In *Perspectivas contemporáneas en la Arqueología Pampeana y Norpatagónica*. Politis G (ed.). Serie Monográfica del INCUAPA 5. FACSO-UNCPBA: Olavarría; in press.

Martínez G, Figuerero Torres MJ. 2000. Sitio arqueológico La Petrona (Pdo. de Villarino, Pcia. de Bs. As.): Análisis de las modalidades de entierro en el área Sur pampeana. *Relaciones de la Sociedad Argentina de Antropología* **XXV**: 227–247.

Martínez G, Zangrando AF, Stoessel L. 2005. Sitio el Tigre (Pdo. de Patagones; Pcia. de Buenos Aires, Argentina): evidencias sobre la explotación de peces en el curso inferior del río Colorado e implicaciones para los sistemas de subsistencia. *Magallania* **33**: 127–142.

Martínez G, Bayala P, Flensborg G, López R. 2006a. Análisis Preliminar de los entierros humanos del sitio Paso Alsina 1 (Pcia. de Buenos Aires). *Intersecciones en Antropología* **7**: 95–108.

Martínez G, Zangrando AF, Prates L. 2006b. Primeros resultados de δ^{13}C y δ^{15}N sobre restos óseos humanos para el curso inferior del río Colorado (Pcia. de Buenos Aires). *'Taller Arqueología e Isótopos Estables en el Sur de Sudamérica. Discusión e Integración de Resultados'. Notas del Museo de Historia Natural de San Rafael* **60**: 17.

Martínez G, Zangrando AF, Stoessel L. 2006c. Use of coastal resources with special attention to fish in the lower basin of the Colorado River (Argentina). *International Council for Archaeozoology* (ICAZ), 10th Conference: D.F. México. Book of Abstracts, pp. 118–119.

Martínez G, Flensborg G, Bayala P, López R. 2007. Análisis de la composición anatómica, sexo y edad de dos entierros secundarios del sitio Paso Alsina 1 (Pdo. de Patagones, Pcia. de Buenos Aires). In *Arqueología en las Pampas*. Vol. 1, Bayón C, Puppio A, González MI, Flegenheimer N, Freire M (eds). Sociedad Argentina de Antropología: Buenos Aires; 41–58.

DOI: 10.1002/oa

Melo W, Schillizzi R, Perillo G, Piccolo MC. 2003. Influencia del área continental pampeana en la evolución morfológica del estuario de Bahía Blanca. *Revista de la Asociación Argentina de Sedimentología* **10**(1): 39–52.

Morello J. 1958. La Provincia Fitogeográfica del Monte. *Opera Lilloana* **2**: 11–155.

Paez M, Schäbitz F, Stutz S. 2001. Modern pollen-vegetation and isopoll maps in southern Argentina. *Journal of Biogeography* **28**: 997–1021.

Pate FD. 1994. Bone chemistry and paleodiet. *Journal of Archaeological Method and Theory* **1**: 161–209.

Perillo G. 1995. Definitions and geomorphologic classifications of estuaries. In *Geomorphology and Sedimentology of Estuaries*, Perillo G (ed.). Elsevier: Amsterdam; 17–46.

Pezzola A, Winschel C, Sánchez R. 2003. Aplicación del SIG para determinar la dinámica de la degradación del monte nativo en el partido de Patagones, Bs. As. Informe Técnico del INTA: Hilario Ascasubi.

Piccolo MC, Perillo G. 1997. Geomorfología e hidrografía de los estuarios. *El mar argentino y sus recursos pesqueros* **1**: 133–161.

Prates L. 2007. *Arqueología del valle medio del río Negro (Provincia de Río Negro)*. Unpublished PhD Dissertation, Facultad de Ciencias Naturales y Museo, UNLP, La Plata.

Prates L, Martínez G, Scabuzzo C. 2006. Evidencias arqueológicas del Holoceno tardío final en el curso medio del río Colorado (Provincia de Río Negro): Sitio Don Aldo 1. *Cazadores Recolectores del Cono Sur. Revista de Arqueología* **1**: 163–177.

Prates L, Scabuzzo C, Mansegosa D. 2007. Investigaciones arqueológicas en el sitio La Victoria 5 (departamento de General Conesa, Rio Negro). MS.

Sánchez R, Pezzola A, Cepeda J. 1998. Caracterización edafoclimática del área de influencia del INTA. EEA Hilario Ascasubi. *Boletín de Divulgación* **18**: 72.

Schäbitz F. 1994. Holocene climatic variations in northern Patagonia, Argentina. *Palaeogeography, Paleoclimatology, Palaeoecology* **109**: 287–294.

Schäbitz F. 2003. Estudios polínicos del Cuaternario en las regiones áridas del sur de Argentina. *Revista del Museo Argentino de Ciencias Naturales* **5**: 291–299.

Schoeninger M. 1995. Stable isotopes studies in human evolution. *Evolutionary Anthropology* **4**: 83–98.

Schoeninger M, DeNiro MJ. 1984. Nitrogen and carbon isotope composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* **48**: 625–639.

Schurr MR. 1998. Using stable nitrogen-isotopes to study weaning behavior in past populations. *World Archaeology* **30**: 327–342.

Sealy J, van der Merwe N. 1986. Isotope assessment and the seasonal-mobility hypothesis in the southwestern Cape, South Africa. *Current Anthropology* **41**: 642–655.

Spalletti L, Isla F. 2003. Características y evolución del delta del río Colorado ("Colú-Leuvú"), Provincia de Buenos Aires, República Argentina. *Revista de la Asociación Argentina de Sedimentología* **10**: 23–37.

Stoessel L. 2006. *Análisis arqueofaunísticos en el curso inferior del río Colorado (Pdos. de Villarino y Patagones, Provincia de Buenos Aires). Aportes para la subsistencia de las ocupaciones indígenas del Holoceno tardío*. Unpublished BA dissertation, Facultad de Ciencias Sociales, UNICEN, Olavarría.

Stoessel L. 2007. Análisis arqueofaunísticos de los sitios Loma Ruíz 1 y El Tigre (partidos de Villarino y Patagones, provincia de Buenos Aires). Aportes para el conocimiento de la subsistencia en el valle inferior del río Colorado durante el Holoceno tardío. *Intersecciones en Antropología* **8**: 235–251.

Tauber H. 1981. ^{13}C evidence for dietary habits of early man in Denmark. *Nature* **292**: 332–333.

Villamil C, Scoffield R. 2003. Evaluación preliminar de la diversidad vegetal en el partido de Villarino (provincia de Buenos Aires). *II Jornadas Interdisciplinarias del Sudoeste Bonaerense, Universidad Nacional del Sur* **3**: 209–219.

Weiler N. 1983. Rasgos morfológicos evolutives del sector costanero comprendido entre Bahía Verde e Isla Gaviota, Provincia de Buenos Aires. *Revista de la Asociación Geológica Argentina* **XXXVIII**: 392–404.

Weiler N. 2001. *Evolución de los depósitos litorales en Bahía Anegada, Provincia de Buenos Aires, durante el cuaternario*. Unpublished PhD Dissertation, Facultad de Ciencias Exactas y Naturales, UBA, Buenos Aires.

DOI: 10.1002/oa