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Stable isotope compositions of South American camelids in the Dry Puna of Argentina: A frame of reference for the study of prehistoric herding and hunting strategies

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ABSTRACT

The prehistoric pastoralist groups that inhabited the Dry Puna of Argentina employed a combination of subsistence strategies that included the herding of domestic South American camelids and the hunting of wild ones since *ca.* 3500 years BP. The relative importance of both subsistence strategies to the prehistoric economy of these groups can be established through traditional zooarchaeological techniques, although how exactly herding and hunting practices developed and interacted both in space and time remains unknown. The general purpose of this work is to provide a tool to explore these questions through stable isotope analyses of animal tissues.

We measured bone collagen $\delta^{13}C$ and $\delta^{15}N$ values of modern *llamas* and *vicuñas*, with the aim to account for the variation in the isotopic compositions of domesticated and wild South American camelids from the Dry Puna of Argentina in order to develop an appropriate frame of reference to address archaeofaunal and paleodietary data. Both $\delta^{13}C$ (n = 140, mean = −18.4 ‰) and $\delta^{15}N$ (n = 109, mean = +6.3 ‰) values showed a negative and significant correlation with altitude for *llamas* and *vicuñas*, which can be explained by the variation identified in plant $\delta^{13}C$ and $\delta^{15}N$ values and their correlation with altitude, as discussed in previous investigations. Based on these results we elaborated linear regressions models for both $\delta^{13}C$ and $\delta^{15}N$ values of both species, which will allow us to predict expected $\delta^{13}C$ and $\delta^{15}N$ values for archaeofaunal materials recovered at archaeological sites using altitude as the explanatory variable.

1. Introduction

One of the main characteristics of highland pastoralism is that it makes use of resources that are heterogeneous in space and time (Genin, 1995). In this sense, most of the contemporary pastoralist groups that inhabit the Andean highlands employ traditional herding strategies that often involve the use of different pastures located in different altitudinal ranges at different moments of the annual cycle. Particularly in the Dry Puna of Argentina, contemporary pastoralist groups maintain various herds and combine the exploitation of several animal species, such as domestic South American camelids (SAC) (*llamas*) and caprines (sheep and goats) (Yacobaccio, 2007). In contrast, the prehistoric pastoralist groups of the same area employed a combination of subsistence strategies that included not only the maintenance and culling of domestic SAC, but also the hunting of wild ones (*vicuñas* and *guanacos*), since *ca.* 3500 years BP (Mengoni Goñalons and Yacobaccio, 2006). The relative importance of both subsistence strategies to the prehistoric economy of Dry Puna pastoralist groups can be established through traditional zooarchaeological techniques (Cartajena et al., 2007; Olivera and Grant, 2009), although how exactly herding and hunting practices developed and interacted both in space and time remains unknown. The general aim of this work is to provide a new tool to explore these questions through stable isotope analyses of animal tissues.

Recently, several studies have explored the potential of stable isotope analyses to investigate prehistoric herding strategies in various parts of the globe (Balasse et al., 2002; Britton et al., 2008; Towers et al., 2011; among many others). In this sense, stable isotope analyses of animal tissues represent a new approach to investigate how human groups exploited and managed animals in the past, allowing us to address issues such as mobility and foddering, which usually escape the scope of traditional zooarchaeological techniques applied to the study of archaeofaunal remains (Balasse et al., 2002; Finucane et al., 2006; Makarewicz and Tuross, 2006; Stevens et al., 2013). Many of these studies employ modern isotopic data as a comparison material to explore variation in archaeofaunal isotopic data (Thornton et al., 2011) and to posit models to test archaeological hypotheses (Balasse and

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Ambrose, 2005). So far, these methods have been applied mostly to the study of domesticated species, but are also useful to study seasonal habitat use, dietary habits, movements and physiology of wild animals also exploited by human groups (Drucker et al., 2012). These are key aspects to deal with palaeoclimatic, palaeoenvironmental and palaeobiological questions but also provide the means to study the hunting strategies employed by human populations in the past (Hartman et al., 2015; Hoppe, 2004).

The main purpose of our work is to account for the variation in the isotopic composition of modern domesticated and wild SAC from the Dry Puna of Argentina and to develop an appropriate frame of reference to address archaeofaunal and paleodietary data. We measured carbon and nitrogen stable isotope compositions on bone material of domestic SAC managed by pastoralists employing traditional herding strategies and wild SAC from previously studied populations, following the lead of previous research performed in the area (Fernández et al., 1991; Fernández and Panarello, 1999-2001a, 1999-2001b; Samec, 2012, 2014; Yacobaccio et al., 2009, 2010). It is important to mention that the $\delta^{13}C$ and $\delta^{15}N$ values presented here were measured on bone collagen, a protein potentially resistant to diagenetic alteration, with the future perspective of using these results in order to interpret isotopic compositions measured on archaeological bones (Bocherens et al., 1996).

As a first step towards the development of an isotopic ecology for the Dry Puna of Argentina, the results discussed here have enormous implications in the investigation of prehistoric herding and hunting strategies, human dietary reconstructions and palaeoenvironmental reconstructions through stable isotope analyses. In this sense, the development of studies that address the variation in the isotopic compositions of plants and animals is one of the main concerns among most users of stable isotope analyses in disciplines like archaeology and paleoecology.

2. The study area: the Dry Puna of Argentina

The Puna of Argentina is located between 22° and 25° S and between 3000 and 5000 masl. This region is a highland desert that contains several NE-SW oriented mountain ranges. It is characterized by wide temperature variation between day and night, high solar radiation and low atmospheric pressure due to altitude. Primary productivity is concentrated on stable hydrological systems such as primary basins, high ravines and wetlands. The only sources of freshwater are a few rivers and several springs scattered throughout the landscape. Precipitation occurs during summertime, governed by the South American monsoon system (Zhou and Lau, 1998). This system produces about 80% of the annual rainfalls between December and February (Vuille and Keimig, 2004). At the same time, precipitation exhibits a NE-SW gradient that delimits two sub-regions within the Dry Puna of Argentina: the north eastern sector with a mean annual precipitation of 300 mm/year; and the south western sector with a mean annual precipitation that barely reach 100 mm/year (Bianchi et al., 2005; Baldassini et al., 2012).

Four main vegetational communities have been identified in the Dry Puna (Cabrera, 1976; Ruthsatz and Movia, 1975; Samec et al., 2017):

1. Shrub steppe (*tolar*) is located between 3500 and 3900 masl. It is dominated by species like *Parastrephia lepidophylla* and *Fabiana densa*, and exhibits a low proportion of herbs (5%). It includes mainly C_3 (shrubs and grasses) and some C_4 (mostly grasses) plant species.
2. Grass steppe (*pajonal*) is located between 4100 and 4700 masl. It is dominated by *Festuca* spp. and other grasses, like *Poa* spp. and *Stipa* spp. It includes predominantly C_3 plant species.
3. Wetlands (*vegas*) are scattered along the landscape between 3500 and 4700 masl. These are restricted patches with high plant cover all year round, mainly composed of hygrophilous grasses such as *Deyeuxia* spp. and *Muhlembergia* spp. These plant communities include mainly C_3 plant species.
4. Mixed steppes are located between 3900 and 4100 masl. These ecotonal landscapes are composed of grasses and shrubs in which mainly C_3 plant species are represented.

3. South American camelids

South American camelids (SAC) are classified into two genera (*Vicugna* and *Lama*) based on their physical appearance and mtDNA sequence data (Wheeler, 1995). Four species are recognized: two wild, the *vicuña* (*V. vicugna*) and the *guanaco* (*L. guanicoe*), and two domesticated, the *llama* (*L. glama*) and the *alpaca* (*L. pacos* or *V. pacos*) (Wheeler, 1995). The origins of SAC domestication and the development of indigenous herding practices are restricted to the Andes, particularly the Central and South-Central portion, since *ca.* 5000 years BP (Yacobaccio and Vilá, 2016). During prehistoric times, domesticated SAC were herded to obtain both primary and secondary products such as meat, hide, fiber and dung, and in the case of the *llama* they were also used as beasts of burden (Mengoni Goñalons and Yacobaccio, 2006). On the other hand, wild SAC were hunted by pastoralist groups to obtain meat supplies, acting as a buffer in periods of shortage, and to use their fiber and hide to make clothes (Yacobaccio, 2009).

The *llama* is the only domesticated SAC that is currently herded in the Dry Puna of Argentina, whereas the *alpaca* is practically absent in the area today as it was in the past given its almost complete absence in the archaeological record of the area (Mengoni Goñalons and Yacobaccio, 2006). At the same time, the *vicuña* and the *guanaco* are the two species of wild SAC that currently inhabit within the Dry Puna of Argentina. The *vicuña* is well distributed within the area, whereas the *guanaco* is present only in small patches along the landscape, an aspect that makes extremely difficult to obtain modern tissue samples. For these reasons, we will focus on *llamas* and *vicuñas*, the most important SAC species in the area both in the present and the past (Fig. 1).

3.1. Traditional herding strategies employed by llama herders

The human groups that currently inhabit the Dry Puna of Argentina base their subsistence on the herding of domestic animals. In this area, livestock is mainly composed of *llamas*, sheep and goats, being these last ones introduced since the Spanish conquest in the XVIth Century (Yacobaccio et al., 1998). *Llama* breeding is mostly oriented towards the production of fiber and meat, whereas sheep are used to obtain wool and meat, and goats are used to obtain meat and milk in good years (Yacobaccio, 2007). Herds feed on natural pastures, only

Fig. 1. A *vicuña* and two *llamas* feeding together in a wetland near the town of Santa Catalina (Jujuy Province, Argentina, 3770 masl) (Photo: Yanina Arzamendia).