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Life History and Origin of the Camelids Provisioning a Mass Killing Sacrifice During the Chimú Period: Insight from Stable Isotopes

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ABSTRACT

The site of Huanchaquito-Las Llamas, situated in the Moche Valley, Peru, dated to the Late Intermediate Period (AD 1100–1470), represents a single event mass killing of children and domestic camelids of the Chimu society. Reconstruction of the life histories of 82 camelid individuals based on stable isotope analysis of bone collagen indicates that they originated from the lowlands. Isotopic inter-individual variability indicates diversity in dietary sources, consisting of wild plants and cultigens, grown in water-limited and non-water-limited conditions, as well as a large proportion of C₄ plants, suggesting that the animals originated from various herds that were differently managed. In contrast, uniformity in terms of restricted coat colour and young age could suggest that the animals derived from specialised herds. It is possible that the requirement in a short period of time for a massive number of animals meeting certain criteria exceeded the capacity of these herds. This study presents the largest isotopic dataset measured at a single pre-Hispanic site so far and the first to record herding practices for the Chimú society. Comparison with previous isotopic datasets shows differences between ritual and non-ritual groups, as well as diversity in pastoralism practises through time in the Central Andes.

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Introduction

Domestic camelids, llamas (*Lama glama*) and alpacas (*Vicugna pacos*), occupied a prominent place in the social, economic, symbolic and ritual life of Andean pre-Hispanic populations. Present in many aspects of everyday life, in particular as suppliers of meat and wool, they were also the driving force of economic exchanges for trade and movement of goods between ecological zones in their role as pack animals (e.g. Browman 1974; Flores Ochoa, MacQuarrie, and Portus 1994; Lecoq 1987; Nielsen 2001). Camelid pastoralism helped foster cultural identity (deFrance 2016). The process of domestication of alpaca and llama may have occurred independently in two different regions between 6,000 and 3,800 BP, in the *puna* (the Andean ecological zone above 3500 masl) of the Central Andes and in the South-Central Andes (southern Peru, north-western Argentina, western Bolivia, and northern Chile) (Cartajena, Núñez, and Grosjean 2007; Mengoni-Goñalons and Yacobaccio 2006; Wheeler 1985; Wheeler, Chikhi, and Bruford 2006).

Nowadays, the *puna* provides suitable pasturelands to sustain large herds, and such herds are absent from lower Andean ecozones. Based on ethnographical and ethnohistorical data, it was traditionally assumed

that camelids present at coastal pre-Hispanic sites were non-local and came from the *puna* through exchange between the coast and the highlands, either as dried meat (*charki*) or as meat on the hoof. More recently, different lines of archaeological evidence have shown that domestic camelids were, in fact, raised locally along the coast at least from the beginning of the Early Intermediate Period (EIP) (200 BC–AD 600), rather than being imported from higher altitudes via coast – highland networks of llama caravans (Bonavia 1996; deFrance 2016; Dufour et al. 2014; Shimada and Shimada 1985; Szpak, Millaire et al. 2014). The difficulty of tracing animal management practices prior to the Late Horizon (AD 1470–1532) relates to the social and economic upheaval caused by the Spanish Conquest in the 16th century. Similarly, the ethnohistorical data on the Inka (Murra 1975) alone do not allow documenting of the complexity of the pre-Hispanic ritual use of camelids.

Domestic animals were the principal animals used for sacrifice in the central Andean region, and among them camelids dominate (Goepfert 2011). Ritual deposits are known from as early as the Late Preceramic (prior to 1800 BC), for example at Kotosh (Izumi and Sono 1963), and they increased dramatically during the Early Intermediate Period, particularly

in the Mochica culture (c. AD 100–800) (Goepfert 2010, 2011, 2012). There was considerable variation in the nature and context of camelid offerings (Millaire 2015). Camelids occurred on their own or in association with buried humans or ritually killed humans, in ceremonial or in domestic contexts (i.e. deFrance 2016; Kent et al. 2016). They are offered as whole animals or as body parts, such as on the coast of northern Peru, where leg extremities are preferentially part of funerary offerings (Goepfert 2012). The mode of death and the number of animals also varied. Variability in ritual practises may relate to the different ritual purposes: for symbolic functions, for alimentary functions, to ensure an owner's welfare, to beg for favours, to appease the rage of the gods or to celebrate the cult of the ancestors and rites of passage (Flores Ochoa, MacQuarrie, and Portus 1994; Millaire 2015).

Different characteristics may have had significance in the choice of animals for ritual and symbolic use (Flores Ochoa, MacQuarrie, and Portus 1994). The predominance of young animals has been reported for sites from different locations and periods (Goepfert 2012; Goepfert and Prieto 2016; Wheeler 2005). Besides, animals of a specific colour might have been selected for particular types of sacrifices. According to the ritual events and the Inca ceremonial calendar, special emphasis was placed on pure brown, black or white animals for sacrifice to specific deities (Murra 1978). Shrine herds owned by the officiants were bred for this purpose and kept apart from state and community herds, primarily in southern Peru (Murra 1975, 1978). Unfortunately, our ability to document the onset of these kinds of practices is limited by the lack of direct archaeological evidence. In southern Peru, 26 sacrificed alpacas and llamas dated from the Late Intermediate Period (LIP) were found underneath a house floor at El Yaral (Moquequa Valley, 1000 masl; Wheeler, Russel, and Redden 1995). The exceptional state of preservation of these naturally mummified animals showed that, with only two exceptions, the requirement for pure coat colour seems to have been met. However, it is unknown whether the El Yaral camelids were sacrificed to the same deities as was the case during Inka times (Wheeler 2005).

The site of Huanchaquito-Las Llamas (hereafter HLL), located in the Moche Valley constitutes the remains of an unprecedented form of mass ritual killing (Prieto et al. 2018; Goepfert et al. 2018) dated to the LIP. Radiocarbon dates and details about the archaeological context can be found elsewhere (Prieto, Goepfert, and Vallares 2015; Prieto et al. 2018). More than 200 domestic camelids, almost exclusively young individuals, were culled during a single event that occurred during the Chimú domination of the northern coast of Peru (Prieto et al. 2018). The dry conditions prevailing on the Peruvian coast have allowed the natural mummification of the animals' bodies at

HLL (Prieto, Goepfert, and Vallares 2015) and hence the observation of the animals' coat colour. In this case, the animals are mostly either brown or dominant brown mixed with beige coat colour and represent a restricted age range (Goepfert et al. 2018; Goepfert and Prieto 2016). The HLL data show that the selection of sacrificial animals for specific biological or physical characteristics predates the Late Horizon; therefore, the existence of specialised husbandries as described for southern Peru can be hypothesised for coastal northern Peru.

The life history of individuals (both humans and animals) that were eventually sacrificed can be inferred from stable isotope analysis (SIA) (Cheung et al. 2017; Dufour et al. 2014; Fernández, Panarello, and Schobinger 1999; Szpak, Millaire et al. 2014; Szpak, Millaire et al. 2016). The present study aims to reconstruct the life histories of 82 of the sacrificial camelids from HLL through the analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of their bone collagen. First, we used SIA to confirm a preliminary report that suggests that highland herds did not serve to provision the HLL mass killing (Prieto et al. 2018). Second, we used dietary reconstruction to infer whether the animals were raised under similar or different breeding conditions with reference to age, coat colour diversity, and spatial distribution within the site. Third, we compared our data with other isotopic datasets published for coastal northern Peru and for southern Peru to elucidate the origin and breeding of the animals that provisioned the mass killing event and discuss pastoral practices.

Environmental and Camelid Variation in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values

The western slopes of the Andes comprise a wide variety of ecological zones (Pulgar Vidal 1981), from the coast to the highlands. This vertical succession of ecozones and the availability of food resource categories, such as C_3 versus C_4 plants, is linked to decreasing mean daily temperature and increasing annual precipitation with increasing elevation (Sandweiss and Richardson 2008). C_3 plants dominate the terrestrial vegetation worldwide and are composed of trees, bushes, shrubs and grasses (Still et al. 2003). C_4 vegetation is mainly composed of grasses and sedges adapted to low humidity environments characterised by high brightness or high temperatures. As a consequence, there will be proportionately more C_4 plants at dry, low altitude locations relative to moister, higher altitude locations, and there will be few C_4 plants in the *puna* (Boom et al. 2001). The most important C_4 cultivar in Andean archaeological contexts is maize (*Zea mays*), which, according to Sandweiss and Richardson (2008) is not cultivated above c. 3500 masl. Variation in vegetation $\delta^{13}\text{C}$ value results, first, from variable carbon fixation during photosynthesis. C_4 plants exhibit

higher values than C₃ plants, while Crassulacean acid metabolism (CAM) plants (composed of desert plants and succulents) exhibit intermediate values (O'Leary 1981; Smith and Epstein 1971). Second, vegetation $\delta^{13}\text{C}$ is affected by a number of environmental factors (i.e. water availability, irradiance).

However, the positive relationship between foliar $\delta^{13}\text{C}$ and altitude and moisture observed in the Andes is countered by the relative distribution of C₃ and C₄ plants (Szpak, White et al. 2013; Tieszen and Chapman 1992). Variation in physical parameters with altitude also influences vegetation $\delta^{15}\text{N}$. A transect along the Moche Valley showed that the foliar $\delta^{15}\text{N}$ value is negatively correlated with altitude and mean annual precipitation (Szpak, White et al. 2013). The effect of altitudinal and environmental variation on $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values seen in wild plants can be blurred in agricultural plants. Andean agricultural fields are commonly supplied with water through irrigation, mediating the influence of local climatic conditions on plant $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (Szpak et al. 2012; Szpak, White et al. 2013). Fields can also be fertilised with camelid dung or bird guano, which also impact (increase) plant $\delta^{15}\text{N}$ values (Szpak et al. 2012). Finally, wild and cultivated plants that obtain nitrogen through a symbiotic relationship with N-fixing microorganisms, such as beans and *algarrobo* (*Prosopis* sp.) trees, which are common on the coast, have lower $\delta^{15}\text{N}$ values than do non-mycorrhizal or arbuscular mycorrhizal plants (Craine et al. 2009; Yoneyama et al. 1993).

The relatively predictable geographical variations in vegetation isotopic signatures across the Andean landmass have enabled researchers to distinguish coastal and low altitude – based camelid husbandry from highlands-based husbandry (Dufour et al. 2014; Szpak, Millaire et al. 2014; Szpak et al. 2015; Szpak, Chicoine et al. 2016; Thornton et al. 2011). But within the general category of low altitude husbandry, which includes the coast, isotopic composition can be expected to vary depending on whether the principal forage was wild plants or agricultural fodder, and whether this fodder consisted of C₄ or C₃ cultigens (Szpak, Chicoine et al. 2016). Camelids herded on the coast or at low altitudes should exhibit relatively high $\delta^{15}\text{N}$ values because they grazed on wild herbaceous or shrub vegetation of coastal river valleys or *lomas* growing under water-limited conditions. *Lomas*, which are oases of fog, develop on the Andean foothills between 200 and 1,000 masl because of winter mists, or *garúa*, which occur between May and December. The modern northern geographic extent of *lomas* is the Cerro Campana, 10 km north of HLL. DeNiro (1988) attributes the high $\delta^{15}\text{N}$, associated with high $\delta^{13}\text{C}$, signatures in camelids at Chilca and La Paloma (Pre-ceramic, southern Peruvian coast) to the consumption of marine or continental aquatic vegetation but the contribution of these resources are thought to be limited.

$\delta^{13}\text{C}$ values of camelids raised in the lowlands are expected to be variable, ranging from low to high, depending of the relative quantities of C₃ and C₄ plants. Because C₃ plant taxa are dominant even in the lowlands, it cannot be ruled out that an individual presenting a low $\delta^{13}\text{C}$ value, indicating a pure C₃ diet, originated from the lowlands. It is supposed that, due to the paucity of natural vegetation, the majority of camelids raised in the lowlands were provided fodder from agricultural products or byproducts (Szpak, Chicoine et al. 2016), although *lomas* may have been more developed in the past and thus may have also constitute a seasonally important resource (Dufour et al. 2014). $\delta^{15}\text{N}$ values of camelids from the highlands are usually lower than 8‰ (values compiled by Szpak, Chicoine et al. [2016]), while animals raised in the lowlands can have higher values due to the consumption of plants subject to water-limited conditions. However, because agriculture is dependent on irrigation, cultigens are not subject to water-limited conditions, and cultigens thus do not exhibit high $\delta^{15}\text{N}$ values (Szpak et al. 2012). C₄ cultigens (such as maize) are mostly present at low altitude and coastal sites. Therefore, coastal camelids foddered with agricultural products or byproducts should be characterised by relatively high, but variable, $\delta^{13}\text{C}$ values, while their $\delta^{15}\text{N}$ should be comparable to those of camelids herded in highland pastures (Dufour et al. 2014; Szpak, Millaire et al. 2014). Camelids intensively foddered with maize should show consistently high $\delta^{13}\text{C}$ values (Finucane, Maita Agurto, and Isbell 2006).

Material and Methods

Site Presentation and Geographic Context

The site of HLL is situated in the valley of the Moche River, in the modern-day city of Huanchaco, 10 km from Trujillo, the capital of the region of La Libertad (Figure 1). It lies on the nearshore of the Pacific Ocean. The Peruvian coast is a sandy, dry environment. This desert environment is the consequence of the quasi absence of precipitation (less than 20 mm per year) prevailing on the coast. However, the coastal landscape is not uniform but, rather, consists of a mosaic of habitats. Water brought by rivers from the Andean mountains sustains natural patches of vegetation along the valleys as well as in irrigated agricultural fields in the valleys and even in the inter-valley zones. Water also occurs seasonally in the *lomas* and is also available locally through the resurgence of the underground water network.

HLL is located close to Chan Chan, the capital city of the Chimú state. ¹⁴C dates of around cal. AD 1400–1450 place the site during the Chimú domination of coastal northern Peru (Prieto et al. 2018). The Chimú conquered the northern Lambayeque state



Figure 1. Map showing the location of the Late Intermediate site of Huanchaquito-Las Llamas and the maximum extent of the Chimú state on the northern Peruvian coast. Relevant archaeological sites and modern cities cited in the text are also shown.

during the mid-fourteen century and became the most powerful political entity in South America (Moore and Mackey 2008). The Chimú state controlled a vast territory of about 1000 km along the Pacific coast, ranging from the modern border between Ecuador and Peru to the present-day capital of Lima (Figure 1). The Chimú state was involved in a large exchange network (Topic 1982) and was sustained by intensive agriculture, with fields fed by a sophisticated web of hydraulic canals (Farrington and Park 1978; Huckleberry, Caramanica, and Quilter 2017; Orloff 1981).

HLL represents the largest Andean mass sacrifice of children and camelids known so far (Prieto et al. 2018), even though part of the site was destroyed by recent human activities. The excavation of c 700 m² during the period 2011–2016 yielded the remains of a total of 140 humans and 206 domestic camelids (Prieto et al. 2018; Goepfert et al. 2018). Stratigraphic evidence indicates that the massive concentration of sacrificed children and camelids represents a single event and not a series of diachronic events (Prieto et al. 2018). Almost all of the bodies were buried at the same depth in the same layer of clean sand and in close proximity to one another, without the burial pits cutting each other. Therefore, it has been concluded that

the sacrificial individuals recovered at HLL were killed contemporaneously, at the sacrificial location (Prieto et al. 2018). Estimation of individual age on the basis of dental eruption and tooth wear (Wheeler 1982). The victims of the sacrifice were almost exclusively young: 137 children *versus* 3 adults and 205 young camelids *versus* 1 adult camelid (Prieto et al. 2018; Goepfert et al. 2018). The reason for the almost exclusive choice of children and young camelids is discussed in Prieto et al. (2018) and Goepfert et al. (2018) and is therefore beyond the scope of this paper. The camelids were mostly carefully accommodated next to, below or on top of the human bodies (Goepfert and Prieto 2016), but also found on their own with up to four camelids together. The camelids were deposited as intact bodies and they were usually in an excellent state of preservation, with the coat preserved and sometimes the stomach contents preserved as well.

Material Selection

The 82 HLL camelid individuals chosen for isotopic analysis were distributed throughout the site (Figure 2). The sampling was representative of the age structure

Spatial distribution of analyzed samples (each dot is a camelid)

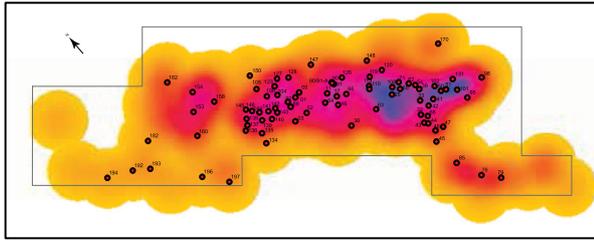


Figure 2. Spatial distribution of the domestic camelids analysed for stable isotopes ($n = 82$) compared with that of the entire population ($n = 206$) at the site of HLL described by a density per core analysis.

and coat colour pattern of the total camelid population (Goepfert et al. 2018). The selected individuals were grouped into 5 age classes: 0–3 months ($n = 12$), 3–12 months (in this case consisting merely of individuals aged 3–9 months) ($n = 44$), 12–24 months ($n = 20$), adult ($n = 1$) and undetermined age ($n = 5$) (Table 1; Supplementary data). The last group consists of juveniles for whom a precise age could not be estimated, for different reasons (lack of skull, fragmented teeth or incoherence in age estimation based on eruption and tooth wear). The fleece colouration of modern llamas and alpacas (both *suri* and *huacaya*) varies from white to black and brown, passing through all intermediate shades. Alpacas show a greater tendency to uniform colouration than do llamas, which have a tendency to spots and irregular colour patterns (Wheeler 2012). At HLL, not all of the possible colourations are represented. The variations that were present were grouped into 5 coat colour groups (Figure 3),

and, like the age groups, these coat colour groups were sampled in proportion to their prevalence in the entire assemblage (Goepfert et al. 2018). The majority of individuals in the SIA sample had either a mixed coat colour dominated by brown ($n = 34$), a uniformly dark brown coat ($n = 18$), or a uniformly light brown coat ($n = 16$). Less common were individuals presenting a uniformly beige coat ($n = 7$) or a coat with a majority of beige ($n = 7$) (Table 1; Supplementary data).

Bone Collagen Preparation and Stable Isotope Analysis

One bone (mandible, phalanx, astragalus or metatarsus) or piece thereof was taken from each of the 82 individuals selected for sampling from HLL (Table 1; Supplementary data) and exported under the permissions obtained from the Ministerio de Cultura of Peru (N°050-2016-VMPCIC-MC). Preparation of about 1 g of bone from each specimen was conducted at the Muséum national d'Histoire naturelle (MNHN) in Paris. The bone surface was first freed from remains of skin and hair. It was then abraded using a tungsten carbide dental tool to remove the cancellous bone and the superficial layer of compact bone that are the most prone to diagenetic alteration. The resulting bone samples were ground to powder-sized grains of between 300 and 750 μm . 150 to 250 mg of powdered bone was demineralised in 1 M HCl for bone collagen extraction. Potential contamination of fulvic and humic acids was removed by NaOH (0.125 M).

Table 1. Summary of isotopic data ($\delta^{13}\text{C}\text{‰}$ VPDB and $\delta^{15}\text{N}\text{‰}$ AIR) for Huanchaquito_Las Llamas camelids.

Age- /colour-group	Number		Bone collagen $\delta^{13}\text{C}$ (‰ VPDB)					Bone collagen $\delta^{15}\text{N}$ (‰ AIR)				
	n	%	Min	Max	Range	Mean	Median	Min	Max	Range	Mean	Median
Whole population	82	100.0	-16.8	-8.3	8.5	-12.5	-12.5	+4.5	+12.1	7.6	+8.3	+8.2
0–3 months	12	14.6	-14.5	-8.4	6.1	-12.0	-12.3	+5.2	+11.3	6.1	+8.0	+7.7
3–9 months	44	53.7	-16.8	-8.3	8.5	-12.4	-12.2	+4.5	+12.1	7.6	+8.2	+8.2
12–24 months	20	24.4	-15.6	-9.7	5.9	-12.8	-12.9	+5.9	+11.9	6.0	+8.6	+8.4
Juv. age undet.	5	6.1	-15.7	-11.8	3.9	-13.4	-13.0	+7.9	+11.4	3.5	+9.0	+8.6
Adult	1	1.2	-14.7	-14.7	–	–	–	+9.3	+9.3	–	–	–
Beige	7	8.5	-16.4	-10.8	5.6	-12.6	-12.5	+5.5	+9.8	4.3	+7.8	+7.6
Light brown	16	19.5	-15.9	-8.4	7.5	-12.6	-12.9	+6.1	+11.4	5.3	+8.5	+8.1
Dark brown	18	22.0	-14.9	-8.3	6.6	-12.5	-12.7	+4.5	+12.1	7.6	+8.5	+8.3
Mixed dom. beige	7	8.5	-15.6	-10.2	5.4	-13.5	-13.1	+6.1	+9.6	3.5	+8.2	+8.4
Mixed dom. brown	34	41.5	-16.8	-9.9	6.9	-12.4	-12.2	+4.6	+11.7	7.1	+8.2	+8.2

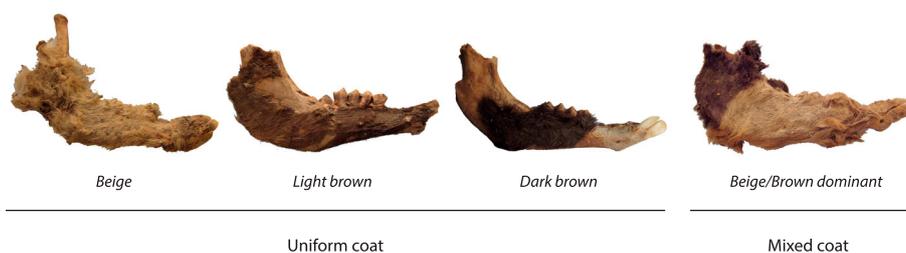


Figure 3. Mandibles from HLL camelids showing the range of coat colour patterns. 3 uniform coat colours are present, namely, beige (a), light brown (b), dark brown (c), as well as mixed brown and beige coats (d). The bicolour coats have been separated into two groups based on the relative proportion of beige and brown in them, for a total of 5 colour groups.

Rather than using the initial NaOH treatment of 17 h recommended by Bocherens et al. (1991), we used the one or several 15–45 min treatments recommended by Szpak, Orchard et al. (2013). One to two treatments were necessary for the solution to run clear. As a final step in the sample preparation, we solubilised the gelatine in warm HCl (0.02 M).

Between 300 and 500 μg of gelatine was combusted using an Elemental Analyser Flash 2000, coupled with a Delta V Advantage (Thermo Scientific) isotope ratio mass spectrometer for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis at the Service de Spectrométrie de Masse Isotopique of the MNHN (SSMM). Mass spectrometer analytical error was estimated to be 0.34‰ for $\delta^{13}\text{C}$ and 0.02‰ for $\delta^{15}\text{N}$, based on replicate analysis of an internal standard (alanine; accepted $\delta^{13}\text{C} = -22.16\text{‰}$ and $\delta^{15}\text{N} = +0.59\text{‰}$) calibrated against the international standard IAEA 600. The repeated analysis of CA-140 and CA-197 provided standard deviations of 0.018‰ and 0.044‰ ($n = 4$) and 0.013‰ and 0.044‰ ($n = 3$) for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, respectively. Values for 29 of the 82 specimens have already been presented in Prieto et al. (2018).

The state of preservation of the collagen was assessed using well established criteria: the atomic C:N ratio (DeNiro 1985); the collagen yield from the whole bone (wt %); and the percentage of carbon (%C) and nitrogen (%N) in the gelatine (Ambrose 1990). The atomic C:N ratio of unaltered bone collagen ranges from 2.9 to 3.6, while the abundance of carbon and nitrogen in modern bone ranges from 13 to 47% and from 4.8 to 17.3%, respectively (Ambrose 1990). Collagen content $>1\%$ is considered to retain preserved stable amino acid composition and produce reliable isotopic values (Dobberstein et al. 2009).

Isotopic Data Treatment

The statistical analyses and graph generations in this study were performed using the statistical software R (version 2.10; R Development Core Team 2010) for Windows and the software Past (Hammer, Harper, and Ryan 2001). The Shapiro–Wilk test was used for testing the normality of the total population. Non-parametric tests were used to compare age groups and coat colour groups because of the small size for some of these groups (for instance, the uniformly beige coat group ($n = 7$) and the mixed coat colour group dominated by beige ($n = 7$)). Kruskal–Wallis, pair-wise Mann–Whitney, and Kolmogorov–Smirnov Leven tests were used to test for equal median, distribution and variance. We used a factor analysis for mixed data (FAMD) performed with the package FactoMineR (version 1.39 [Pagès 2004]) to test for homogeneity and the distance between the groups across both qualitative (age and coat colour) and quantitative

($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values) variables. The influence of both continuous and categorical variables in the analysis is balanced in order to ensure that they equally determine the dimensions of variability. Elliptical contours were generated at a confidence level of 0.95.

The distribution of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values was described using multivariate, ellipse-based metrics (Jackson et al. 2011) calculated using the R package SIAR (Parnell and Jackson 2013). The Bayesian-based area metrics, or SIBER (Stable Isotope Bayesian Ellipses in R [Jackson et al. 2011]), were used to quantitatively evaluate the extent of HLL intra-group dietary variability at a confidence level of 40%. HLL metrics were then compared with those of other camelid groups from the literature. Four area metrics based on the spread of bivariate stable isotope data were produced: SEA (standard ellipse areas or covariance matrix), SEA_B (standard ellipse areas with Bayesian estimate), and SEA_C (standard ellipse areas corrected for sample size) and TA (convex hull areas that enclose all the bivariate variability) (Jackson et al. 2011). SEA_B is a probabilistic estimation of the SEA comprised of a set of iterative posterior draws, using a Markov chain Monte Carlo (MCMC) simulation (10^4 draws were used). SEA_B are used to generate density plots showing the credible intervals of the standard ellipse area of the camelid groups. HLL ellipse metrics and TA were compared with those of different camelid populations from the literature. Significant differences between HLL SEA_B and the SEA_B of these populations were calculated as the percentage of ellipse areas for the HLL group that are larger than the ellipse areas for each of these populations (Jackson et al. 2011). Values of 0 and 1 mean that the HLL ellipse is always larger or smaller, respectively, than that of the ellipse of the comparative population (SEA_{B group 2}). A value of 0.5 means that the two populations have equal sized ellipses.

The relative contributions of C₃ and C₄ plants were quantified with the SIAR package, using a single isotope Bayesian mixing model. The source values represent means \pm one standard deviation of wild and cultivated plants sampled in northern Peru (Szpak, White et al. 2013): $-26.12 \pm 1.75\text{‰}$ and $-12.01 \pm 0.95\text{‰}$ for C₃ and C₄ plants, respectively. Modern plant values need to be adjusted to account for the burning of fossil fuels over the past 150 years, which has increased the $\delta^{13}\text{C}$ of atmospheric CO₂ (the Suess Effect). A correction of $\sim 1.5\text{‰}$ (Marino and McElroy 1991) was applied. A trophic fractionation occurs when the food carbon is incorporated into the tissues of animals. A collagen – diet spacing value of $+3.6 \pm 1.7\text{‰}$ was used for bone collagen (Szpak, Millaire et al. 2014).

An agglomerative hierarchical clustering of isotopic values was performed using the Past software.

Finally, an analysis of densities per core was performed using the Kernel density tool of the software

package Arcgis (<http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-kernel-density-works.htm>) to describe the spatial distribution of camelid remains in the vicinity of each other at the HLL site (Figure 2).

Results

Isotopic values ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) and elemental (C, N) compositions for all specimens ($n = 82$) analysed are presented in the Supplementary data. All specimens produced collagen with atomic C:N ratios (from 3.1 to 3.6) and carbon and nitrogen abundances (from 24.6 to 43.3% and from 8.0 to 16.1%, respectively) within the range of accepted values for well-preserved bone collagen. All collagen yields were $>1\%$, with a mean value of 15.6%, confirming the very good state of bone collagen preservation at HLL. Accordingly, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of all specimens were used in this study (Table 1 and Supplementary data).

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of the HLL camelids varied from -16.8 to -8.3‰ and from $+4.5$ to $+12.1\text{‰}$, respectively, exhibiting a range of values of 8.5 and 7.6‰, respectively (Table 1; Figure 4). The population variability based on the spread of bivariate stable isotope data was expressed by metrics (TA, SEA, SEA_C) and presented in Table 2. There was no statistically significant difference in median, distribution and variance either among the 5 age-groups or the 5 colour-groups for univariate isotopic values (either $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$) (Figure 5). We performed a FAMD on all juveniles for which age had been estimated ($n = 76$), using isotopic, age and coat colour data. The youngest age group (0–3 months), which comprised only 7 specimens, appeared slightly separated from the other two age groups (Figure 6). Similarly, the beige colour group, which comprised 4 individuals 0–3 months old, was slightly separated from the other 4 basic colour groups. However, this separation was not strong since the first 2 components of the FAMD only explained 34% of the

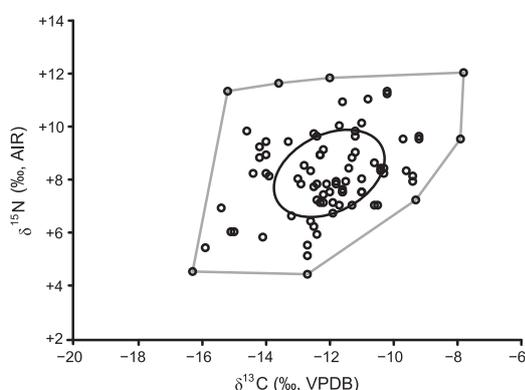


Figure 4. Bone collagen $\delta^{13}\text{C}$ (‰; VPDB) and $\delta^{15}\text{N}$ (‰; AIR) values of 82 camelids from HLL. The polygon is the convex hull area that encompasses the variability for all individuals. The ellipse represents the bivariate standard deviation (40% confidence).

Table 2. Summary of the ellipse area metrics.

Coat colour-group	<i>n</i>	TA	SEA	SEA_C
All individuals	82	47.2	8.5	8.6
All aged juveniles	76	43.1	8.3	8.4
Mixed colour	40	28.3	7.1	7.3
Uniform	36	39.8	9.8	10.1
Uniform brown and brown dominant	62	43.1	8.5	8.7
Uniform beige and beige dominant	14	5.2	6.8	7.3

TA = total area of convex hull, SEA = standard ellipse area, SEA_C = standard ellipse area corrected for sample size for Huanchaquito-Las Llamas camelids calculated to assess the inter-individual variability. Metrics were calculated for the entire population as well as for the groups defined based on coat colour.

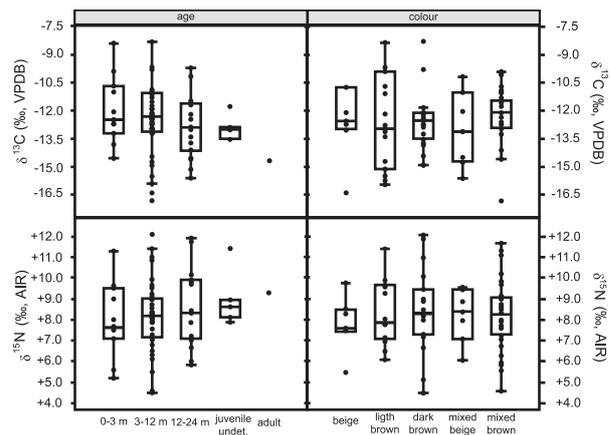


Figure 5. Box-plot comparison of $\delta^{13}\text{C}$ (‰; VPDB) and $\delta^{15}\text{N}$ (‰; AIR) values measured in bone collagen of camelids from HLL grouped by age (left) and coat colour (right). Age and coat colour groups were not significantly different regarding both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (Kruskal-Wallis and Mann Whitney, $p < 0.001$).

variance (Figure 6). Grouping the colour groups into larger categories, for example uniform *versus* bicolour or beige *versus* brown, did not reduce the inter-individual variability as expressed by SEA and SEA_C values (Table 2). It even increased it for the uniform colour pattern (Table 2), indicating that within these categories were gathered individuals with different life histories. Thus the age and colour parameters as they were categorised here do not explain the intra-population variability. Agglomerative hierarchical clustering without *a priori* individual grouping provided a large number of clusters (not shown). The clusters were composed of a small number of individuals of various ages and colours, in concordance with the rather homogeneous repartition of individuals across the overall range of isotopic bivariate plot (Figure 4). Despite the apparent grouping of beige coat in Figure 6, only three individuals of this coat colour, all aged 0–3 months old, were distributed in the same cluster. Finally, the analysis of the spatial repartition of the age, colour of coat, and combination of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotopic values indicated that animals with these different characteristics did not show differential spatial clustering over the site (Figure 2). Mean relative contributions of C_3 and C_4 plants to the diet of the HLL

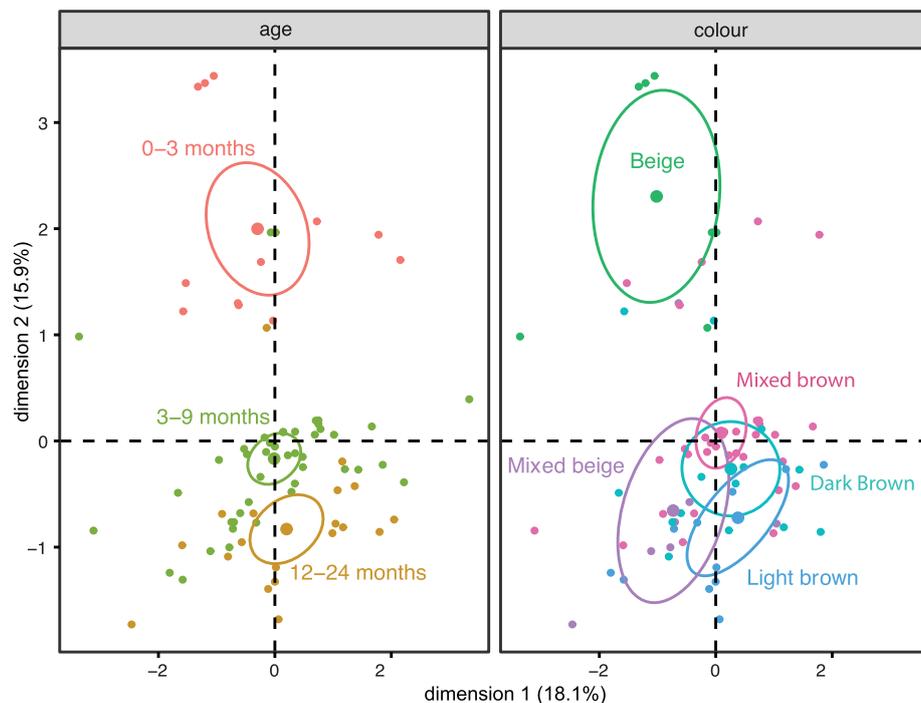


Figure 6. Factor analysis of mixed-data (FAMD with 95% confidence ellipse) with quantitative ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) and qualitative (3 age groups and 5 coat colour groups) data for the 76 juveniles for which age in months could be estimated.

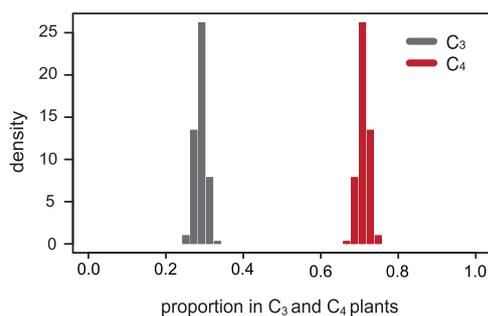


Figure 7. Plot of relative contributions of C_3 and C_4 plants to the diet of HLL camelids as determined by the SIAR isotopic mixing model and bone collagen $\delta^{13}\text{C}$.

population were 29.4% (95% of Bayesian credible interval: 26.7–32.0%) and 70.6% (95% of Bayesian credible interval: 68.0–73.3%), respectively (Figure 7).

Discussion

Reconstruction of HLL Camelid Diet and Herding

Stable isotope analysis of human and animal remains found in archaeological contexts is a primary source of information on the life history of humans and animals. In combination with knowledge of environmental variation and availability of local resources, stable isotope analysis can allow for the reconstruction of diet and dietary practices as well as mobility patterns of past populations. In the Andes, two criteria have been used to discriminate between camelids originating from the lowlands *versus* the highlands (Dufour et al. 2014; Szpak, Millaire et al. 2014; Thornton et al. 2011):

the amount of within group-variability and the proportion of C_4 vegetation in the diet that varies. SIA covering 40% (82 of a total of 206) of the HLL population shows that camelids at the site are characterised by high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, a large variation in both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ as well as a positive correlation between $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Figure 4; Table 2). This pattern is clearly different from that observed for modern camelids herded on the high-altitude pastures of the *puna*. *Puna* camelids are characterised by both low inter-individual variability (low TA and SEA metrics) and low $\delta^{13}\text{C}$ values because C_4 plants are minor components of the diet compared with C_3 plants (Dufour et al. 2014; Szpak, Millaire et al. 2014). None of HLL specimens had a 100% C_3 diet, and the mean population contribution of C_4 plants was about 70% (Figure 7). Moreover, the median $\delta^{15}\text{N}$ value for the HLL population is 8.2‰, indicating that half of the population isotopic composition is higher than the highest values characterising modern highland camelids (values compiled by Szpak, Chicoine et al. 2016). We can conclude, therefore, that the sacrificial animals from HLL did not originate from the highlands. A ‘local’ origin is in accordance with the young age of the camelids. According to ethnohistorical and ethno-biological data, cargo animals incorporated into caravans only began training after spending their first two years in the *puna* (Lecoq 1987; Nielsen 2001). Moreover, the presence of very young animals has been considered indirect evidence for the ‘local life’ (whether temporary or permanent) of their parents. Indeed, during the gestation period, the females are

gregarious and are not moved from their environment (Wheeler 1991).

We know from the recovery context that the variability in camelid $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ at HLL is not a consequence of the kind of long temporal accumulation that usually characterises archaeological sites. It therefore implies that the sacrificial individuals recovered at HLL lived (part of) their life contemporaneously before eventually being killed at the same time at the sacrificial location. What, then, accounts for the inter-individual variability in camelid $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ at HLL? Nursing is another possible cause of inter-individual variability in $\delta^{15}\text{N}$. $\delta^{15}\text{N}$ of bone collagen represents the weighted average of dietary intake over a long period of time. Suckling (or breastfeeding) causes an increase of $\delta^{15}\text{N}$ in the tissues of the suckling young compared with the tissues of its mother (Newsome et al. 2006). Its impact on $\delta^{15}\text{N}$ is thought to depend on the relative contribution of milk and plants as the young animal acquires a herbivorous diet at weaning and on collagen turn-over rate. The absence of statistical differences in $\delta^{15}\text{N}$ among the age groups at HLL (Figure 5) suggests that suckling has no confounding effect on $\delta^{15}\text{N}$ variability at the intra-population level, despite the slight discrimination of the 0–3 month group (Figure 6). This does not preclude the possibility that the $\delta^{15}\text{N}$ values of the entire population were influenced by the effect of suckling. This overall effect could blur the effect caused by the consumption of fertilised plants or plants growing on arid soils. The effects of suckling on $\delta^{15}\text{N}$ should also be taken into consideration when populations composed of young individuals are compared with populations composed of adults.

The variability in values and the absolute values of the HLL camelids must therefore reflect dietary diversity. The camelids consumed, in variable proportions, diverse wild and cultivated plants characterised by different isotopic compositions. A most salient observation for the diet of HLL camelids is the moderate to very large proportion of C_4 compared to C_3 plants (Figure 7). $\delta^{15}\text{N}$ values are high, which reveals the proportionately large consumption of plants growing under conditions of water stress or under the influence of fertilisation (both of which increase the $\delta^{15}\text{N}$ values of plants), as well as the restricted importance of nitrogen-fixing plants. Nitrogen-fixing plants are characterised by low $\delta^{15}\text{N}$ values when they are not fertilised (Szpak, Longstaffe et al. 2014). The differences in proportion are the consequence of the practices and choice of herders who sustain their livestock with grazing and with foddering by different types of cultigens. The natural coastal environment is not considered productive enough to sustain large herds. Foddering of animals with maize or maize byproducts – animals could have fed on maize stubble after the harvest – could have been a solution used by the herders in the lowlands, as has previously been suggested in the

same valley for the Mochica period (Dufour et al. 2014). $\delta^{13}\text{C}$ values measured at HLL and El Brujo Cao (Lambayeque culture) (Santana-Sagredo et al. 2018) are the highest measured for the north coast. They are comparable to the values exhibited by some of the camelids analysed from the sierra site of Conchopata (2700 masl) (Finucane, Maita Agurto, and Isbell 2006). At Conchopata, intensive consumption of maize was also suggested for humans, revealing the importance of this staple in the economy of the Wari polity (AD 550–1000) (Finucane, Maita Agurto, and Isbell 2006). In contrast to Conchopata, at HLL, the highest $\delta^{13}\text{C}$ values are associated with high $\delta^{15}\text{N}$. One possible explanation for the positive correlation between $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ is that some camelids (characterised by relatively low $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values) fed mainly on C_3 plants grown in non-fertilised fields or lands (such as algarrobo trees), while others (characterised by high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values) fed mainly on maize grown either in fields fertilised by guano or manure or in fields that were not irrigated. Agriculture without irrigation seems, unlikely, however, in an arid environment. An alternative explanation for these values is that the camelids fed on the local *loma* vegetation, as suggested for 3 camelids found in a ceremonial context at the highland site of Cerro Baúl (Wari culture, AD 600–1000) (Thornton et al. 2011). The natural (non-irrigated) vegetation of *lomas* is mostly composed of C_4 and CAM plants and therefore would provide dietary resources characterised by high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. Another potential natural resource characterised by high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values consumed by the camelids is the *grama salada* (*Distichlis spicata*), a wild, salt-tolerant C_4 grass. *Grama salada* could have constituted a sustainable grazing resource because it is widespread, naturally covering large patches along coastlines and as part of desert scrub habitat.

Despite showing clear variations in diet, the distribution of values for the entire HLL group is rather continuous along the overall isotopic range. There is no grouping of animals into strong and discrete isotopic clusters or clustering of individuals of various colour patterns and ages within the larger distribution, with the possible exception of some of the young beige animals, which may be slightly grouped (Figure 6).

All sacrificed camelids from HLL were raised ‘locally’ on the coast or in the middle valleys and fed on a variety of resources in proportions reflecting the choices made by herders for their animal management. The stable isotope results are consistent with two different scenarios. The animals sacrificed at HLL could have originated from different herds that lived spatially separated prior to their culling, or they could have been managed differently at a same location. While it is difficult to decipher which of the two scenarios pertained in the past, the most likely and simple explanation is that the animals were

obtained from various herds that were differently managed. It is more difficult, though not impossible, to imagine a scenario in which animals raised by the same breeders grazed very differently. We would expect similarity in diet and, related to that, low intra-group variability in isotopic composition, especially for a group exhibiting a very limited age range.

Provision of Sacrificial Camelids at HLL

HLL is a unique example of a mass killing of children and camelids during the pre-Hispanic period. While the motivation for the mass sacrifice is not known, it is thought to be associated with a sudden climatic event (heavy rainfall and flooding) that could have impacted the economic, political and ideological stability of the kingdom (Prieto et al. 2018). The sacrifice necessitated the provisioning of a large number of animals over a very short period of time. The officiants could have met this quick and large provisioning need by selecting animals at random. Despite animals of restricted age range and coat colour diversity were targeted. Selection of animals with physical attributes has been documented for a ritual in a domestic context during the LIP at El Yaral (Wheeler, Russel, and Redden 1995) and for Inka times in southern Peru (Murra 1978). The SIA results suggest that the animals sacrificed at HLL originated from various herds, and this raises the question of whether the officiants preparing for the sacrifice selected animals of a specific origin among the overall availability of types of husbandry at the time. If they did, the camelids at HLL may not represent the full extent of herding practices on the northern portion of the Peruvian coast during the Chimú domination.

Comparisons are made difficult by the lack of contemporaneous datasets. The bone collagen dataset from HLL can, however, be compared with 3 datasets of camelids used for ritual purposes on the northern portion of the Peruvian coast. Studies were conducted in the Chicama Valley, on funerary contexts at Cao Viejo-El Brujo (Santana Sagredo et al. 2018) (Middle Horizon), and in the Virú Valley, on sacrificial contexts at Huaca Santa Clara (late Middle Horizon, AD 1100) (Szpak, Millaire et al. 2014) and Huancaco (Middle Horizon, AD 778–979) (Szpak, Millaire et al. 2016). Comparison with SEA metrics is not appropriate for the Huancaco group, because it is composed of only a small number of individuals ($n = 10$), but comparison with SEA_C and SEA_B metrics is appropriate (Jackson et al. 2011). When compared with other ritually used groups, inter-individual variability in the HLL group is higher than in 2 of them (Huancaco and El Brujo) and similar to 1 of them (Huaca Santa Clara) (Figures 8 and 9; Table 3). When compared with non-ritually used groups, inter-individual variability in the HLL group is lower than in 3 of them – recovered in the

Virú Valley at the sites of Huaca Santa Clara (EIP, AD 400–600) and Huaca Gallinazo (EIP, AD 250–400) (Szpak, Millaire et al. 2014) – and similar to 1 of them (Huaca Gallinazo (EIP, AD-50-250) (Figures 8 and 9; Table 3). According to Szpak et al. (2014), the smaller inter-individual variability for the sacrificed camelids at Huaca Santa Clara is a likely product of the restricted individual age range, the small accumulation duration for a sacrifice and the small size of the group. However, our dataset suggest that the group size is not the dominant factor. HLL and Huaca Santa Clara sacrificed group share comparable inter-individual variability, they are both time snapshot groups comprised of young animals, but HLL is composed of a considerably larger number of individuals (Table 3). Both groups present higher stable isotope variability than the Cao Viejo-El Brujo funerary group, which is composed of individuals exhibiting a larger biological age range, accumulated over a longer period of time. Due to the paucity of data and the

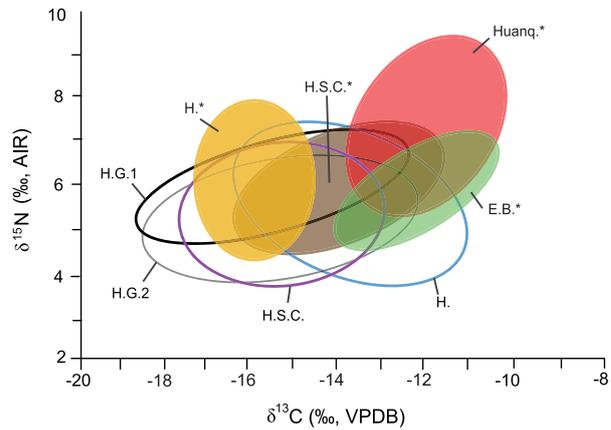


Figure 8. Comparison of inter-individual variability in $\delta^{13}C$ and $\delta^{15}N$ values for camelid groups (with 40% confidence ellipses) recovered from 4 ritual (indicated by shaded ellipse areas) and 4 non-ritual (empty ellipse areas) contexts on the northern Peruvian coast. Full name of each group is given in Table 3.

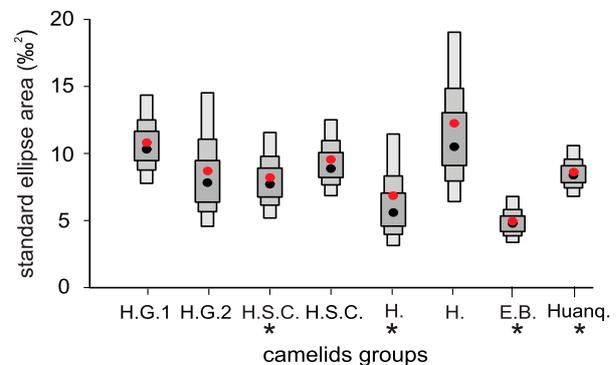


Figure 9. Density plot depicting standard ellipse areas (SEA_B) for each camelid group presented in Figure 8 and expressed as resultant uncertainty. Shaded boxes represent the 50%, 75% and 95% credible intervals, from dark to light grey. Red dots represent SEA_C (standard ellipse area corrected for sample size) for each group.

Table 3. Comparison of the ellipse area metrics.

Site	Reference	Age	Valley	Context	<i>n</i>	TA	SEA	SEA _C	SEA _B Huanchaquito > group 2
Huaca Gallinazo (H.G.)	Szpak, Millaire et al. (2014)	50 BC-AD 250	Virú	Non ritual	13	20	8.0	8.8	0.4815
Huaca Gallinazo (H.G.)	Szpak, Millaire et al. (2014)	AD 250-400	Virú	Non ritual	43	40.9	10.6	10.8	0.1165
Huaca Santa Clara (H.S.C.*)	Szpak, Millaire et al. (2014)	AD 1100	Virú	Sacrifices	25	24.1	7.8	8.1	0.611
Huaca Santa Clara (H.S.C.)	Szpak, Millaire et al. (2014)	AD 400-600	Virú	Non ritual	43	48.2	9.3	9.5	0.316
Huancaco sacrifices (H.*)	Szpak, Millaire et al. (2016)	AD 778-979	Virú	Sacrifices	10	14.2	6.0	6.8	0.818
Huancaco (H.)	Szpak, Millaire et al. (2016)	AD 550-680	Virú	Non ritual	14	30.7	11.3	12.2	0.1325
El Brujo-Cao Viejo (E.B.*)	Santana Sagredo et al. (2018)	AD 1000	Chicama	Funerary	36	17.3	4.7	4.8	0.9945
Huanchaquito (Huanq.*)	This study	AD 1400-1450	Moche	Sacrifices	82	47.2	8.5	8.6	–

TA = total area of convex hull, SEA = standard ellipse area, SEA_C = standard ellipse area corrected for sample size for different groups of camelids recovered from both ritual (groups indicated by *) and non-ritual contexts of the northern coast of Peru. SEA_B Huanchaquito > group 2 is the proportion of ellipse areas generated through Markov Chain Monte Carlo with 10⁴ iterations for Huanchaquito group that are larger than ellipse areas for each comparative group (group 2).

lack of contemporaneous ritual and non-ritual datasets, it is difficult to conclude whether the restricted inter-individual variability for ritual groups is linked to the choice of individuals from a selection of herds or to a more restricted pattern of herding practices at a given time and place in the lowlands. This question should be explored in the future by through SIA of animals from a wide range of contexts.

The selection of animals with biological and physical attributes reported by chroniclers for Inka times in southern Peru was linked to the existence of specialised herds of varying sizes providing animals for different purposes (meat, wool, labour, ritual). The fact that animals sacrificed at HLL came from various herds neither validates nor invalidates the existence of specialised husbandries, whether or not specialised in the production of a particular colour pattern, dedicated to sacrifices during Chimú times. An exceptional weather event – for example, the heavy rain that can occur during the warm phase (El Niño) of the El Niño–Southern Oscillation phenomena – might have resulted in such an exceptional and massive demand that it might have exceeded the normal capacity of specialised herds. It would have then required the participation of a larger range of husbandries to provision the sacrifice with young individuals with targeted characteristics. An argument in favour of this hypothesis is the absence of a gathering of individuals sharing the same isotopic composition at the site (Figure 2). The human and camelid footprints discovered at HLL provide evidence that the humans and the animals came from areas to the north and south of the site and walked to the centre of the sacrificial area (Prieto, Verano, and Goepfert 2017). We would expect that animals coming from the same herd would have arrived together and then been placed in burial pits close to each other after sacrifice but this is not the case. Finally, we would also expect some kind of gathering of animals according to their colour pattern during life or at death and thus their placement in burial pits close to each other after sacrifice. This was not the case at HLL but we should not forget that the categorisation into colour patterns (5 groups, unicolour *versus* bicolour or mostly beige *versus* mostly brown) used in the present study

was done through our modern perception of the physical aspects of the animals. The perception – and then selection – of animals by the officiants might have been different and not accessible to us.

Instead of picking animals from specific herds, the ritual practices might have included animals that were maintained together for a short period before the culling. Short-term dietary changes cannot be inferred from collagen analysis. Such change can only be detected through the SIA of incremental tissue growing throughout the life of the animal, such as hair, or at a certain period of time, such as tooth enamel (Dufour et al. 2014). Isotopic tracers directly related to the geographic origin of breeding, such as ⁸⁷Sr/⁸⁶Sr and δ¹⁸O values, could be used to reconstruct animal residential mobility (Goepfert et al. 2013; Knudson, Gardella, and Yaeger 2012) and thereby provide independent, complementary insight into the origin of the camelids that provisioned the sacrifice.

Conclusions

The Huanchaquito-Las Llamas mass sacrifice represents a previously unknown sacrificial ritual from fifteenth-century northern coastal Peru. The exceptional conditions of preservation provide a unique opportunity to glimpse aspects of the nature of the event that are usually not accessible to archaeologists. In particular, we were able to elucidate the circumstances of the death, some biological and physical characteristics, as well as the life history of sacrificed animals. Yet despite these data, the reasons behind the choice of animals remain difficult to comprehend. Sacrifices are complex cultural events that have to be set in their social, political and economic context. The present isotopic dataset, the largest produced so far for a sample group at a site, sheds light not only on ritual practices but also on the complexity and diversity of pastoralism during pre-Hispanic times. Camelid remains have been recovered from numerous coastal sites, but herding practises in this area have only recently begun to be explored. So far very little was known about camelid management during the Chimú domination of the northern portion of the Peruvian

coast. The present study extends the documentation of animal keeping on the coast, which may have been initiated at the end of the Early Horizon (Szapak, Chicoine et al. 2016) and became established during the Early Intermediate Period (Dufour et al. 2014; Szpak, Millaire et al. 2014). It also adds to the growing evidence for the existence of local systems of production in the past that were distinct from the Inka highland husbandry model, both in southern (Thornton et al. 2011) and northern Peru (Dufour et al. 2014; Szpak, Millaire et al. 2014). Based on SIA and on the presence of small stone enclosures containing camelid dung dated from the EIP and late Middle Horizon in the Virú Valley, Szpak, Millaire et al. (2014) have argued that northern coastal camelid husbandry consisted primarily of numerous small groups of animals kept within or around urban environments by individual households. In contrast, our data support the existence of large-scale management practices to provision a mass sacrifice with a large number of young animals with diverse life histories that will not provide their meat, wool or labour. Management of several large herds grazing on different territories and landscapes of the Moche Valley would explain the diversity in diet that was revealed by SIA. The contribution of domestic camelids to the Chimú society reached an unprecedented importance for northern coastal societies. Domestic camelids were not just used for large-scale sacrifices and offerings in burials; they were also essential for good trading (Topic 1982) and as a source of dietary protein. According to Pozorski (1976), they represented 95% of the diet of the Chimú people. Altogether, these elements suggest a high level of organisation and control of lands and resource production by the Chimú state.

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