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An Integrated isotopic study of Early Intermediate Period camelid husbandry in the Santa Valley, Perú

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ABSTRACT

Stable carbon and nitrogen isotope compositions were determined for camelid bone collagen, hair, and wool (fibre) sampled from textiles from archaeological sites in the Santa Valley (north coast of Perú) occupied during Moche III (El Castillo, A.D. 300–500) and Moche IV (Guadalupito, A.D. 500–700) phases; a small number of camelid bone collagen samples were also analysed from the Late Suchimancillo Phase (A.D. 0–300). These data suggest that localised camelid husbandry was practiced in the Santa Valley from at least the Moche III phase. The nature of camelid husbandry likely involved animals being kept spatially segregated and fed a diverse range of fodder. The isotopic compositions of the bone collagen and wool textiles were very similar, which suggests that the wool that was used to produce the textiles was derived from local camelids rather than being acquired from the highlands. The transition from Moche III to Moche IV, which saw a significant increase in Mochica presence in the Santa Valley, was not accompanied by major changes in camelid husbandry practices. Localised camelid husbandry continued through this transition with minimal change; the prolonged droughts of the sixth century A.D. had no discernable effect on camelid husbandry, probably due to the special hydraulic conditions unique to the Santa Valley.

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Stable isotopes; animal management; camelids; Moche; craft production; textiles

Introduction

South American camelids, particularly the llama (*Lama glama*) and alpaca (*Vicugna pacos*), were known to be extremely important in the Andean region from ethnohistoric (Murra 1965, 1980, 1962) and ethnographic records (Nielsen 2001; Browman 1987, 1990a, 1990b; Flannery, Marcus, and Reynolds 1989). The ethnohistoric records provide detailed accounts of camelid husbandry around the time of the Spanish conquest and have been influential in informing archaeological interpretations of human-camelid interactions (Bonavia 2008). An explicit element in these records is the association of llamas and alpacas with the highlands (Murra 1965, 1980, 1962). In this context, 'highlands' refers to the high altitude pastures (>3,800 masl) of the *puna*. Similarly, the influential geographer Carl Troll (1958) firmly associated camelids with the highlands, suggesting that any domestic camelids living elsewhere were anomalous, being introduced by the Inka state and clearly not part of any established local tradition. While it is apparent that camelids were domesticated in the highlands (Moore 2016; Wing 1986), it is becoming increasingly clear that the maintenance of resident camelid populations at lower altitudes and specifically in many of the coastal river

valleys was common (Bonavia 2008). Shimada and Shimada (1985) presented a comprehensive argument based on ethnographic, ethnohistoric, and zooarchaeological data and concluded that camelids were kept on the coast since the early Middle Horizon (c. A.D. 600) and possibly earlier. More recently, isotopic data have played a major role in these discussions. Using isotopic baselines from local plants collected from different altitudes (Szpak et al. 2013) and a growing body of data from archaeological camelid skeletal remains (Szpak, Millaire, et al. 2016; Szpak, Chicoine, et al. 2016; Szpak et al. 2015; Szpak et al. 2014; Dufour et al. 2014; Thornton et al. 2011; Dufour et al. 2018), it is possible to assess aspects of the animals' life histories, specifically the kinds of environments in which they lived.

On the basis of isotopic data collected from camelid skeletal remains it appears as though camelids were being raised on the north coast of Perú by at least the Early Intermediate Period (EIP) in the Virú Valley (c. 50 B.C.) (Szpak et al. 2014) and possibly beginning in the Early Horizon in the Nepeña Valley (c. 450 B.C.) (Szpak, Chicoine, et al. 2016). Because the number of studies conducted and the number of samples analysed are very limited from a spatiotemporal perspective, no

clear picture exists with respect to the origins of coastal camelid husbandry or its causal mechanism(s), its distribution in space and time, and how it may have interacted with local political economies and environmental perturbations that were known to be significant in the region (Van Buren 2001; Dillehay and Kolata 2004; Dillehay, Kolata, and Pino 2004; Sandweiss et al. 2007).

While camelids were certainly important as a source of meat, both in the highlands and on the coast (Rosenfeld and Sayre 2017; Pozorski 1979; Lau 2007; Pozorski 1982), their greatest value may have been in their wool. Camelid wool was used to craft both elaborate and utilitarian textiles, which were the most important markers of identity and status in the Andean region (Oakland Rodman 1992; Millaire 2009; Boytner 2004; Surette 2015). In fact, Bird (1954) speculated that a motivating factor for the initial domestication of camelids in the highlands was the demand for wool by coastal weavers. Isotopic analyses have been applied to wool textiles recovered from the arid coast of Perú and contrary to the predominant line of thinking that has viewed alpaca wool as originating in the highlands and moving to the coast via trade (Rowe 1980; Boytner 2004), wool originating on the coast, or at the very least outside of the high altitude pastures, has been observed at both the EIP occupation at Huaca Santa Clara in the Virú Valley (Szpak et al. 2015) and the Late Intermediate Period (LIP) occupation at Pacatnamú in the Jequetepeque Valley (Szpak et al. 2018). It is unclear if this wool would have been derived from alpacas or llamas, a matter that is complicated by the existence of a greater variety of breeds prior to the Spanish Conquest (Wheeler, Russel, and Redden 1995). In line with traditional thinking, wool textiles associated with the LIP Chancay tradition from the central coast of Perú appear to be made exclusively with highland wool acquired via long-distance exchange (Szpak et al. 2015). At the very least a simple mode of camelid husbandry did not exist in the Andean region and was likely variable across space and time. From an isotopic perspective, moving towards a more comprehensive understanding of the nature of camelid husbandry requires the consideration of data derived from both skeletal remains and wool. This study presents stable carbon and nitrogen isotope compositions of camelid skeletal remains, hair from naturally mummified camelids, and wool sampled from textiles from sites in the Santa Valley predominantly associated with Moche III (A.D. 300–500) and Moche IV (A.D. 500–700) occupations.

Isotopic and Environmental Context

The materials analysed as part of this study are derived from four sites in the lower Santa Valley although most of the material comes from two of these. The environment is broadly similar to the other valleys of the north

coast (Szpak et al. 2013; Sandweiss and Richardson 2008; Rundel et al. 1991; Kornbacher 2002). Comprehensive overviews on the environmental factors influencing plant $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values provide a platform for interpreting results from this particular environment (Szpak 2014; Craine et al. 2015; Farquhar, Ehleringer, and Hubick 1989; Ehleringer, Hall, and Farquhar 1993; Högberg 1997; Kohn 2010).

In northern Perú, there are several important environmental changes that occur in moving from the Pacific coast to the highlands, which have an effect on the isotopic compositions of soils and plants. The coast, which is extremely arid, is characterised by a relatively large proportion of C_4 biomass and high $\delta^{15}\text{N}$ values in wild plants (Szpak et al. 2013); it does not appear that cultivated plants, fed by irrigation, are characterised by these high $\delta^{15}\text{N}$ values (Szpak, Millaire, et al. 2012). As the elevation increases, mean annual temperature decreases and mean annual precipitation increases, leading to a pattern where the abundance of C_4 plants declines with increasing altitude and wild plant $\delta^{15}\text{N}$ values decrease (Szpak et al. 2013).

As a result of these environmental gradients, animals, such as camelids, living at different altitudes in the Andes tend to be characterised by distinct isotopic compositions. This is not to suggest that knowing the stable carbon and nitrogen isotope compositions of an individual camelid bone or wool fragment will provide a definitive origin, rather when larger groups of samples from individual sites are characterised, arguments can be made about the probability that the group can be associated with a particular type of environment. Camelids raised on high altitude pastures are characterised by consistently low $\delta^{13}\text{C}$ values (<30% C_4 plants in the diet) and low overall isotopic variation (Szpak et al. 2015; Thornton et al. 2011; DeNiro 1988; Szpak 2013). On the basis of archaeological studies, camelids that were likely raised on the coast are characterised by a diverse range of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values with the mean contribution of C_4 plants at the group level being in the range of 40–70% (Szpak, Millaire, et al. 2016; Szpak et al. 2014; Szpak et al. 2018; Tomczyk et al. 2018; Dufour et al. 2018). A third pattern that has only been observed at the Wari site of Conchopata located at c. 2,700 masl is a bimodal distribution of camelid $\delta^{13}\text{C}$ values with one group consuming predominantly C_3 plants (similar to the highland camelids) and the other group consuming predominantly C_4 plants (>75%), suggestive of intensive maize (*Zea mays*) foddering (Finucane, Agurto, and Isbell 2006). Strictly speaking, this intensive maize foddering strategy could be employed at any elevation wherein maize is cultivated and a sufficient amount of fodder could be provided to camelids. Therefore, while it has only been observed at Conchopata, it is plausible that a similar strategy could also

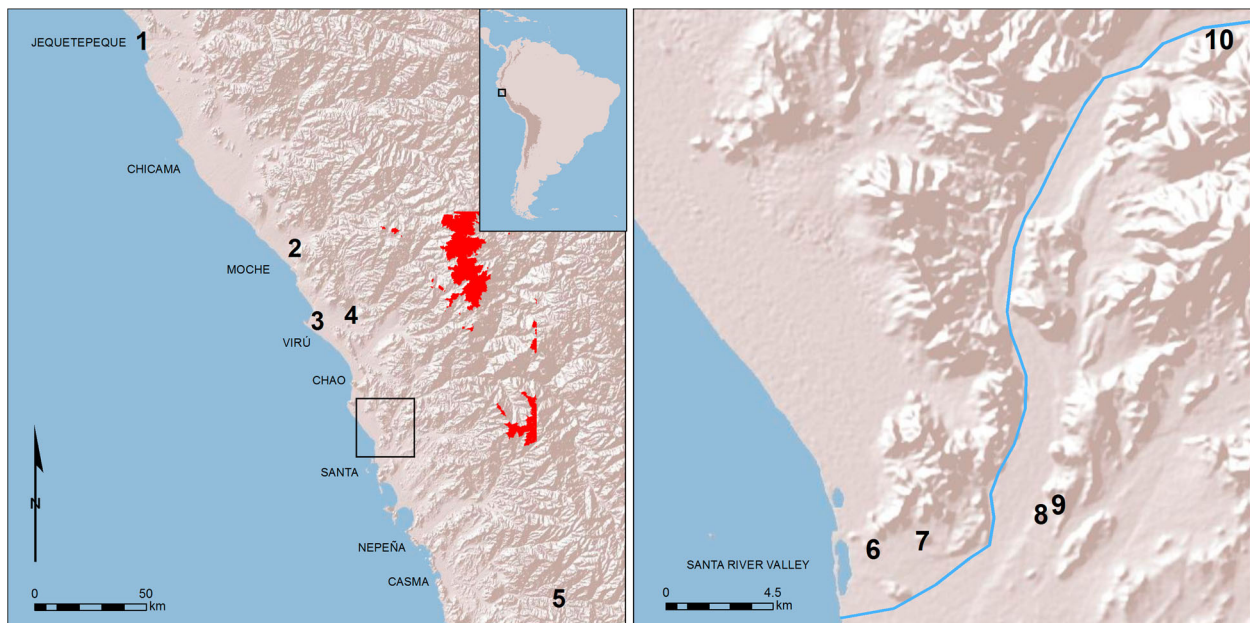


Figure 1. Left panel: Map of the central Andes showing sites mentioned in the text: (1) Pacatnamú, (2) Huacas de Moche, (3) Huaca Gallinazo (V59), (4) Huaca Santa Clara (v67), (5) Chinchawas. The shaded area indicates areas with elevation >3,800 masl. Right panel: Map of the Santa Valley showing sites analysed as part of this study: (6) LSUCH-145, (7) Guadalupito, (8) El Castillo, (9) GUAD-88, (10) LSUCH-103.

be employed at lower altitudes and along the coast, particularly in more urbanised settings where the provisioning of animals with fodder is required. In summary, the two most significant variables for assessing the nature of camelid husbandry are the relative proportion of C_4 plants in the diet (directly related to the $\delta^{13}C$ value) and the amount of bivariate isotopic variation (assessed on the basis of the bivariate standard ellipse area). Even though wild coastal plants have significantly higher $\delta^{15}N$ values than those growing at higher altitudes (Szpak et al. 2013), $\delta^{15}N$ values have not proven to be a particularly useful marker for coastal camelid husbandry because agricultural byproducts from irrigated fields (not subject to the severe water limitation of wild coastal plants) were likely the primary food source for camelids.

Archaeological Context

The Santa Valley is located in the southern region of the north coast of Perú (Figure 1). Extensive surveys were conducted in the 1960s and 1970s by Donnan (1973) and Wilson (1988). These surveys identified the presence of Moche material culture in the lower Santa Valley, signalling the presence of a ruling Moche polity. The nature of this Moche occupation was not well understood, but has recently become clearer with more intensive excavations at several important sites. Prior to the arrival of Moche material culture in the Santa Valley, it was inhabited by a local EIP group referred to as Suchimancillo by Wilson (1988) and Gallinazo de Santa by Chapdelaine (Chapdelaine, Pimentel, and Gamboa 2009). Moche is

associated with the development of a complex form of government traditionally associated with archaic states (Service 1975; Feinman and Marcus 1998). Over the years, the nature of Moche political organisation was documented through research on Moche art and iconography (Pillsbury 2001), burial patterns (Donnan 1995; Millaire 2002), irrigation systems (Billman 2002), civic and residential architecture (Castillo and Uceda 2008), warfare (Quilter 2002), and through the refinement of relative and absolute chronologies (Quilter and Koons 2012). However, the nature of Moche political organisation is still debated (Quilter 2010; Quilter and Castillo 2010), with interpretations ranging from a single monolithic state (now discarded) to two (Northern Moche and Southern Moche) or more (city-state like) polities, each in control of its own hinterland (Castillo and Donnan 1994; Millaire 2010a). It is also unclear if Moche represents a case of primary or secondary state formation in the region (Millaire 2010b; Spencer 2010).

On the basis of both survey and excavation, the Moche III occupation of the Santa Valley appears to have been very limited (Chapdelaine 2010). Most evidence of a Moche III occupation comes from the site of El Castillo, which may have been a regional centre or outpost established by the Moche around A.D. 300 (Chapdelaine 2008) after it had served as an important political or civic-ceremonial centre for the local population during the EIP (Chapdelaine, Pimentel, and Gamboa 2009). This site is unusual within the context of the establishment of Moche regional centres in that it was constructed in an area that was already occupied, suggesting it is not representative of a Moche conquest

Table 1. Summary of the sites included in the analysis and the materials sampled from those sites.

Site	Period	<i>n</i> Bone Samples	<i>n</i> Hair Samples (<i>n</i> Segments)	<i>n</i> Textile Samples
LSUCH-103	Late Suchimancillo	2		
LSUCH-145	Late Suchimancillo	3		
El Castillo	Moche III	38	19 (58)	60
GUAD-88	Moche III			3
Guadalupito	Moche IV	7		37

of the Santa Valley but possibly an attempt to establish diplomatic relations with local elites (Chapdelaine 2010). The northern terrace of El Castillo has yielded an abundance of materials associated with the Moche III occupation (Chapdelaine, Pimentel, and Gamboa 2009; Chapdelaine 2011a) and these materials represent a substantial portion of the sample analysed in this study including camelid bones, hair from naturally mummified camelid parts, and wool textiles (Table 1).

Guadalupito was an important Moche IV centre and it appears that the site was occupied only after El Castillo had been abandoned. Guadalupito was subsequently intensively occupied for around one century beginning some time between A.D. 600 and 700 (Chapdelaine 2010) and probably lasted until A.D. 800 (Chapdelaine 2011a). While during Moche III evidence of Moche presence is limited predominantly to El Castillo and some minimal material culture from sites located in its immediate vicinity, Moche IV sees the presence of Moche material culture throughout the Santa Valley (Wilson 1988; Chapdelaine 2008). Moche IV was characterised by a much more direct occupation of the valley by Moche elites and potentially colonists from the heartland of the southern Moche state (Chapdelaine 2010).

The timing of the transition from the Moche III to Moche IV occupations of the Santa Valley around A.D. 500–600 is noteworthy from an environmental perspective. This period was characterised by prolonged regional droughts (Thompson et al. 1985), which may have had a significantly negative impact on agricultural productivity in some areas of northern Perú (Shimada et al. 1991). These droughts, punctuated by strong ENSO events accompanied by significant flooding, have previously been speculated to have caused the decline of the Moche state (Moseley and Richardson 1992). Conversely, Chapdelaine (2000) presented new radiocarbon dates and settlement data from the Huacas de Moche site that demonstrated Moche continuity through these environmental disruptions. Nonetheless, these ecological crises may have served as an impetus for the Moche to commence a concerted effort at expansionist conquests of the southern valleys of the coast, including Santa (Chapdelaine 2010). Regardless of any direct connection to environmental change, there was some significant reconfiguration of the Moche polity on the north coast around this time (Swenson 2007; McClelland 1990; Bawden 1996; Chapdelaine 2011b; Shimada

1994), and changes in water management and agricultural productivity may have played an important role in these reconfigurations.

It is possible that significant shifts in the use of camelids and camelid products (i.e. wool textiles) in the Santa Valley would have occurred with the transition from Moche III to Moche IV. In this study we investigated the following questions:

- (1) Was localised camelid husbandry practiced in the Santa Valley during the EIP and if so was it comparable to what has been observed for the EIP in the Virú Valley (a large amount of isotopic variation among individuals and a relatively high [c. 50%] contribution of C_4 plants to the diet on average)?
- (2) Did environmental changes decrease agricultural productivity, making the rearing of camelids in the local environment impractical or impossible? Such a change should be characterised by evidence of camelids with coastal isotopic signatures in Moche III (as outlined for Question 1) and highland signatures (relatively low among individual isotopic variation and a small contribution of C_4 plants to the diet [c. 20%] on average) in Moche IV.
- (3) Did the Moche introduce camelid husbandry to the Santa Valley during Moche IV driven by a growing population? In this scenario we might expect camelid bones and textiles to have isotopic compositions consistent with an origin in the highlands during Moche III, but coastal isotopic compositions during Moche IV. Alternatively, localised camelid husbandry may have initially been practiced at a small scale during Moche III but a more intensive type of husbandry, perhaps associated with intensive maize foddering, may have been introduced during Moche IV.

Materials and Methods

Materials

Three different types of materials were sampled: bone ($n = 50$), hair from naturally mummified camelids ($n = 24$ individuals, $n = 66$ total samples by segment) not associated with bone samples, and wool sampled from textiles ($n = 101$). Table 1 provides a summary of the sample types and numbers of samples taken

from each of the sites. The bone collagen samples were derived from three periods: (1) Late Suchimancillo ($n = 5$), corresponding to the local material culture tradition present in the region prior to the arrival of Moche, (2) Moche III ($n = 38$), derived from the northern terrace of El Castillo, (3) Moche IV ($n = 7$), from Guadalupito. The Late Suchimancillo bone samples were derived from two sites: LSUCH-103 ($n = 2$), located in the middle Santa Valley and LSUCH-145 ($n = 3$), located on the coast. The bone samples were identified only as camelids as the differentiation between llamas and alpacas is quite difficult in the absence of crania. All bones were first proximal phalanges. The textiles were derived only from Moche III ($n = 60$) and Moche IV ($n = 41$) contexts. The naturally mummified camelids were not offerings deposited whole, as has been observed at other sites on the north coast (Millaire 2015; Goepfert and Prieto 2016), but butchered elements that contained relatively small amounts of skin and hair.

Sample Preparation

Samples of bone were removed using a Dremel rotary tool equipped with a diamond-tipped cutting wheel. These samples were ground using a Plattner mortar and sieved to isolate the fragments that were between 0.018 and 2.0 mm in diameter. The collagen extraction protocol has been modified from Longin (1971). Collagen was extracted by demineralising ~500 mg of these fragments in 0.5 M HCl (ACS Reagent Grade, Fisher, Fair Lawn, New Jersey) at room temperature. Once the samples were demineralised they were rinsed to neutrality with deionised water and those that exhibited dark colouration were treated with 0.1 M NaOH (ACS Reagent Grade, Fisher, Fair Lawn, New Jersey) at room temperature for successive 20 min treatments until there was no colour change in the solution. Following this, samples were rinsed to neutrality with deionised water and then 4 ml of 10^{-3} M HCl (ACS Reagent Grade, Fisher, Fair Lawn, New Jersey) was added and the collagen was refluxed at 90°C for 18 h. The solution containing the soluble collagen was then transferred to glass vials and air-dried at 90°C.

For the textile samples, any visible particulate matter was first removed using fine forceps and a dental pick. A sample was then cut from the fragment and sonicated in deionised water for 20 min (von Holstein et al. 2016). Samples were centrifuged and air-dried at 60°C, and then treated with 2:1 chloroform:methanol (both HPLC grade, Fisher, Fair Lawn, New Jersey) for 30 min (Bowen et al. 2009). The samples were centrifuged again, the solvent solution was removed and the samples were air-dried at 60°C.

Hair samples were prepared in the same manner as the textile samples, but prior to the first wash with deionised water the samples were cut into 1 cm

increments, where possible. For samples <2 cm in length, one sample representative of the entire length was taken.

Stable Isotope Analysis

Isotopic and elemental compositions were determined using a Thermo Scientific Delta V continuous flow isotope ratio mass spectrometer coupled to a Costech Elemental Analyzer at the Laboratory for Stable Isotope Science (The University of Western Ontario). Stable carbon and nitrogen isotope compositions were calibrated to VPDB and AIR with USGS40 (glutamic acid, accepted $\delta^{13}\text{C} = -26.39$ ‰, $\delta^{15}\text{N} = -4.52$ ‰) and USGS41 (glutamic acid, accepted $\delta^{13}\text{C} = +37.63$ ‰, $\delta^{15}\text{N} = +47.57$ ‰) or USGS66 (glycine, values $\delta^{13}\text{C} = -0.67$ ‰, $\delta^{15}\text{N} = +40.83$ ‰). Analytical accuracy and precision were monitored using a suite of internal and international standards interspersed among the samples, and 28 samples were analysed in duplicate. Standard uncertainty was determined to be ± 0.21 ‰ for $\delta^{13}\text{C}$ and ± 0.23 ‰ for $\delta^{15}\text{N}$ (Szpak, Metcalfe, and Macdonald 2017); additional details are provided in the Appendix (Tables S1–S4).

Data Treatment

Bone collagen samples characterised by the following criteria were included in the analysis: wt % collagen yield >1%, wt % C >13%, wt % N >4.8%, $2.9 \leq \text{C:N}_{\text{atomic}} \leq 3.6$ (Ambrose 1990; DeNiro 1985). There are no empirically-derived quality criteria for isotopic measurements of ancient hair, although von Holstein et al. (2014) found minimal changes to the carbon and nitrogen isotope compositions of wool fibres with experimental degradation (also see von Holstein et al. 2016, for additional discussion). Boudin et al. (2016) suggested that the atomic C:N ratio is a robust indicator of preservation for wool used in ^{14}C dating, with a range between 3.4 and 3.8 producing reliable results. Therefore, to eliminate samples with isotopic compositions altered by degradation or contamination the same logic was employed as was used in the original collagen quality studies (Ambrose 1990; DeNiro 1985): samples with particularly low wt % C (<25%) or wt % N (<8%) or anomalous C:N ratios ($3.4 \leq \text{C:N}_{\text{atomic}} \leq 3.8$) were noted and their isotopic compositions were excluded from further analyses if they were judged to be unusually high or low with respect to other samples from a given group.

The relative contributions of C_3 and C_4 plants to camelid diets were estimated using a single isotope ($\delta^{13}\text{C}$) two-source mixing model in the SIAR package (Parnell et al. 2010). The source carbon isotope compositions were taken from published plant values for the Moche Valley region (Szpak et al. 2013): -26.12 ± 1.75 ‰ for C_3 plants and -12.01 ± 0.95 ‰ for C_4

plants. The following trophic enrichment factors (TEFs) were used in the mixing model based on averages calculated for multiple controlled feeding and field studies: $+2.4 \pm 1.2$ ‰ for hair keratin (Szpak 2013) and $+3.7 \pm 1.6$ ‰ for bone collagen (Szpak, Orchard, et al. 2012). The amount of isotopic variation within each group was quantified using the standard bivariate ellipse computed in the SIBER package (Jackson et al. 2011). Groups of animals consuming isotopically similar foods produce smaller standard ellipse areas than groups of animals consuming variable proportions of isotopically distinct foods. Comparisons of isotopic variation among groups were made using the Bayesian standard ellipse area (SEA_b). In this procedure, 10^4 ellipses are created and comparisons are made between the ellipse sizes from each group (Jackson et al. 2011). This allows for a calculation of the percentage of ellipse areas for Group 1 that are larger than the ellipse areas for Group 2, with 0.5 representing equal sized ellipses and 0 and 1 representing situations where the Group 1 ellipse is always larger (0) or smaller (1) than the Group 2 ellipse. It is important to note that these values are not equivalent to *p*-values and are more useful for qualitative rather than strictly quantitative interpretation of the relative amount of isotopic variation between groups, with no set value being associated with true statistical significance. When the ellipse areas for the hair samples for El Castillo were compared to other groups, each hair segment was treated as a unique sample. The SIBER and SIAR calculations were performed using R 3.0.3 for Mac OS 10.13.4 (R Core Team 2016).

To make comparisons of isotopic compositions among different groups, normality was assessed with a Shapiro–Wilk test. Because some of the groups being compared were not normally distributed, a Mann Whitney U test was then used to assess differences in the median $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ between groups. When different tissues were compared (bone collagen vs. hair/textile) the hair/textile $\delta^{13}\text{C}$ were adjusted by $+1.3$ ‰ to account for differences in tissue-specific TEFs (Szpak et al. 2015). These statistical tests were performed using SPSS 23 for Mac OS 10.13.4.

Because of the small sample size for the camelid bone from the two Late Suchimancillo sites, these sites were always grouped together for summary

statistics and statistical comparisons. For comparative purposes, four different sets of published stable carbon and nitrogen isotopic compositions were used that best represented the different types of camelids and are characterised by the most robust sample numbers for each type:

- (1) Camelid bone collagen from the EIP occupation (A.D. 250–450) at Huaca Gallinazo in the Virú Valley ($n = 43$) (Millaire 2010b). These data best represent bone collagen from camelids that most likely lived in a coastal river valley (Szpak et al. 2014).
- (2) Camelid bone collagen from the Middle Horizon occupation at Chinchawas located at 3,850 masl in the Department of Ancash ($n = 13$) (Lau 2007). These data best represent bone collagen from a highland camelid herding site (Szpak et al. 2015).
- (3) Wool textiles from the Late Intermediate Period occupation (A.D. 1100–1320) at Pacatnamú in the Jequetepeque Valley ($n = 118$) (Donnan and Cock 1986; Boytner 1998). These data best represent textiles most likely derived from coastal camelid wool (Szpak et al. 2018).
- (4) Wool textiles associated with the Late Intermediate Period (A.D. 1100–1435) Chancay culture from the central coast of Perú ($n = 58$) (Asil 2015). These data best represent textiles from highland camelids that were traded to the coast (Szpak et al. 2015).

Results

Stable carbon and nitrogen isotopic and elemental compositions for all samples analysed are presented in the Appendix (Tables S5–S7) and summarised in Table 2. All bone samples produced collagen that passed all of the quality criteria discussed above. A single hair segment from El Castillo had low wt % C (29.3%) and wt % N (9.4%) values and a very low $\delta^{15}\text{N}$ value ($+2.7$ ‰). The $\delta^{15}\text{N}$ values of hair segments immediately before and after this one had $\delta^{15}\text{N}$ values of $+6.7$ ‰ and $+6.3$ ‰. Accordingly, the data produced from this segment were excluded from further analyses.

Table 2. Summarised stable carbon and nitrogen isotope compositions for the camelid bone collagen, hair, and textile fragments analysed in this study (means \pm one standard deviation).

Site(s)	Dates	Material	<i>n</i>	$\delta^{13}\text{C}$ (‰, VPDB)	$\delta^{15}\text{N}$ (‰, AIR)
LSUCH-103	A.D. 0–300 (Late Suchimancillo)	Collagen	2	-19.34 ± 0.19	$+5.57 \pm 0.81$
LSUCH-145 ¹	A.D. 0–300 (Late Suchimancillo)	Collagen	3	-19.61 to -11.48	$+5.22$ to $+6.99$
El Castillo	A.D. 300–500 (Moche III)	Collagen	38	-14.25 ± 2.29	$+7.87 \pm 1.96$
Guadalupito	A.D. 500–600 (Moche IV)	Collagen	7	-15.15 ± 3.05	$+7.36 \pm 1.89$
El Castillo	A.D. 300–500 (Moche III)	Hair ²	57	-15.85 ± 1.76	$+8.39 \pm 1.40$
El Castillo	A.D. 300–500 (Moche III)	Textile	60	-15.87 ± 2.29	$+7.71 \pm 1.45$
Guadalupito	A.D. 500–600 (Moche IV)	Textile	40	-16.29 ± 1.91	$+7.55 \pm 1.29$

Notes: Ranges are given for the samples from LS-145. The mean values presented for the hair treat each segment (rather than each individual animal) as a distinct sample.

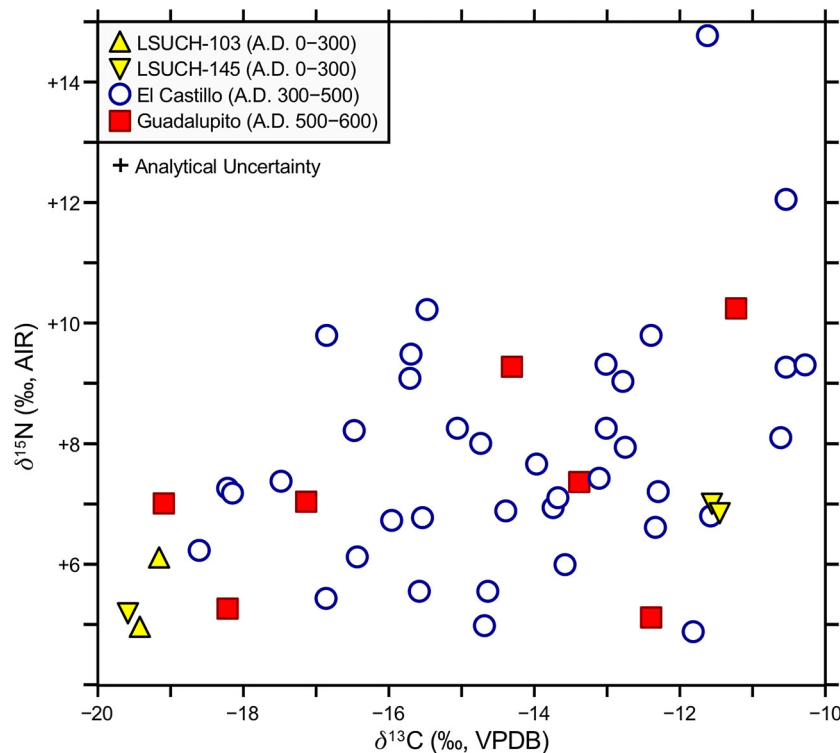


Figure 2. Stable carbon and nitrogen isotope compositions for camelid bone collagen from El Castillo (Moche III) and Guadalupito (Moche IV).

The bone collagen stable carbon and nitrogen isotope compositions for the material analysed in this study are presented in Figure 2. There were no significant differences among the three groups of camelid bone collagen from the Santa Valley with respect to $\delta^{13}\text{C}$ (Table 3). The camelid bone collagen from El Castillo and Guadalupito had $\delta^{13}\text{C}$ values that were significantly higher than those from the high altitude herding site of Chinchawas (Table 3). In comparison to the suspected coastal camelids from Huaca Gallinazo, the camelids from Guadalupito had $\delta^{13}\text{C}$ values that were not significantly different ($p = .63$). On the other hand, the camelid bone collagen from El Castillo was characterised by significantly higher $\delta^{13}\text{C}$ values than Huaca Gallinazo ($p = .03$); the magnitude of this difference was 1.4 ‰. The El Castillo camelid bone collagen $\delta^{15}\text{N}$ values were significantly higher than those from Huaca Gallinazo ($p = .001$), but did not differ significantly from the Chinchawas camelids ($p = .23$). There were no significant differences in $\delta^{15}\text{N}$ between the camelid bone collagen from Guadalupito and Huaca Gallinazo or Chinchawas (Table 3). The five bone collagen samples from the two Late Suchimancillo sites were characterised by a seemingly bimodal distribution, with three of the lowest and two of the highest $\delta^{13}\text{C}$ values among all of the samples (Figure 2). Given this unusual distribution and the small sample size, meaningful statistical comparisons of these samples are not possible.

The textile stable carbon and nitrogen isotope compositions are presented in Figure 3 and the results for the

statistical comparisons among the textiles and hair samples from the sites analysed as part of this study and the comparative sites are presented in Table 4. There were no significant differences between the $\delta^{13}\text{C}$ ($p = .35$) or $\delta^{15}\text{N}$ ($p = .58$) values for textiles from the residential and civic-ceremonial contexts at Guadalupito.

After accounting for tissue-specific TEFs, the bone collagen $\delta^{13}\text{C}$ values from El Castillo were significantly higher than textiles from the same site ($p = .001$), with the difference between the means being 1.6 ‰; there was no significant difference in $\delta^{15}\text{N}$ ($p = .49$). The Guadalupito bone collagen did not significantly differ from the textiles from that site for either $\delta^{13}\text{C}$ ($p = .24$) or $\delta^{15}\text{N}$ ($p = .77$).

The stable carbon and nitrogen isotope compositions of serially-sampled hairs from El Castillo are presented in Figure 4. For the sake of clarity only data for those hair samples with ≥ 3 analysed segments are presented in Figure 4; data for all other hair samples analysed are presented in Table S7 and included in the statistical calculations except for the single sample noted above. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of the camelid hair at El Castillo were both significantly higher than the textile $\delta^{13}\text{C}$ ($p = .002$) and $\delta^{15}\text{N}$ ($p = .003$) values from that site; the differences between the means was 1.3 ‰ for $\delta^{13}\text{C}$ and 0.7 ‰ for $\delta^{15}\text{N}$. After accounting for tissue-specific differences in TEFs the El Castillo hair had statistically indistinguishable $\delta^{13}\text{C}$ values relative to the El Castillo bone collagen ($p = .49$), but significant higher $\delta^{15}\text{N}$ values ($p = .04$), with the difference in $\delta^{15}\text{N}$ being 0.6 ‰.

Table 3. Results of the statistical comparisons of the camelid bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (p -values for Mann-Whitney U tests).

		Moche III (El Castillo)	Moche IV (Guadalupito)	Huaca Gallinazo (probable coastal collagen)	Chinchawas (highland collagen)
$\delta^{13}\text{C}$	Late Suchimancillo (LS-103,145)	.31	.37	.61	.37
	Moche III (El Castillo)	—	.49	.03	<.001
	Moche IV (Guadalupito)	—	—	.63	<.001
	Huaca Gallinazo (probable coastal collagen)	—	—	—	<.001
$\delta^{15}\text{N}$	Late Suchimancillo (LS-103,145)	.02	.09	.37	.24
	Moche III (El Castillo)	—	.56	.001	.23
	Moche IV (Guadalupito)	—	—	.26	.72
	Huaca Gallinazo (probable coastal collagen)	—	—	—	.40

Note: p -Values $<.05$ are indicated in boldface.

The results of the mixing model and the analysis of the bivariate ellipse areas are summarised in Table 5 and Figure 5. The same range of metrics is presented in Table 5 for the four comparative datasets outlined previously. There was more isotopic variation present in the bone collagen datasets from El Castillo and Guadalupito than for the textile datasets from the same sites. The estimated ellipses for the El Castillo camelid bone collagen were larger than the textile ellipses in 86.5% of the comparisons, while the estimated Guadalupito camelid bone collagen ellipses were larger than the textile ellipses in 97.6% of the comparisons; this latter value was driven to a large degree by the small sample size of the Guadalupito collagen dataset. There was more variation in the El Castillo textiles than the Guadalupito textiles, with the El Castillo ellipses being larger than the Guadalupito ellipses in 98.1% of the comparisons. The camelid hair from El Castillo produced a much smaller set of bivariate ellipses than the bone collagen from that site, with

the hair ellipses being smaller than the collagen ellipses in 99.7% of the comparisons. The El Castillo hair ellipses were also smaller than the textile ellipses from the same site in 95.5% of the comparisons, but were larger than the Guadalupito textile ellipses in 70.8% of the comparisons.

Discussion

Local Camelid Husbandry

Returning to the first research question, the stable carbon and nitrogen isotope compositions of the camelid tissues and textiles are consistent with other archaeological data that have been interpreted to represent animals raised in the coastal river valleys. We therefore suggest that camelids were being herded locally in the lower Santa Valley by Moche III. The data from the Late Suchimancillo period (Figure 2) are reminiscent of the bimodal carbon isotope compositions presented

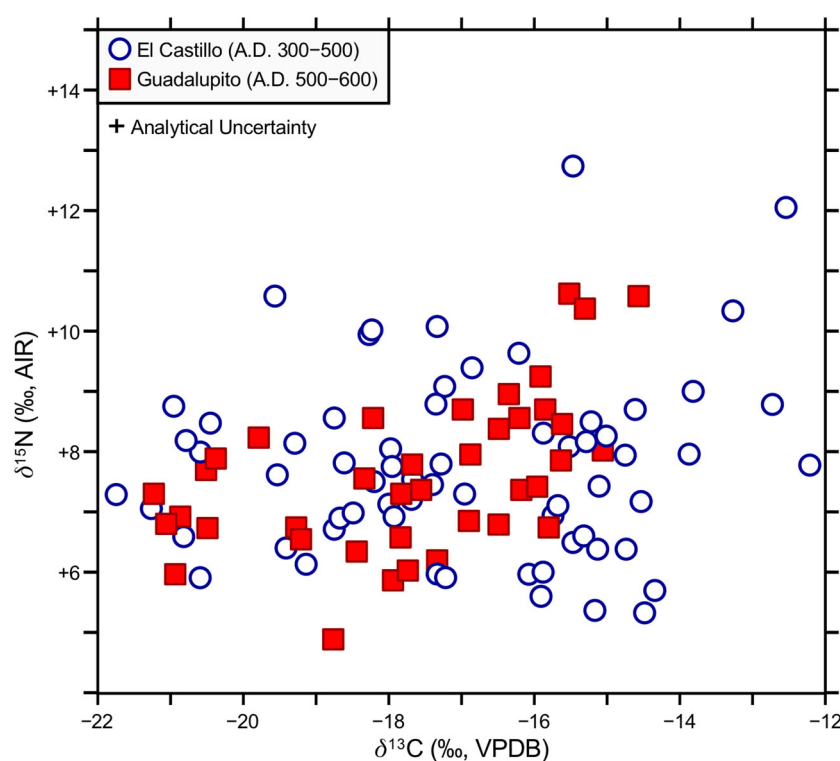
**Figure 3.** Stable carbon and nitrogen isotope compositions for textile fragments from El Castillo (Moche III) and Guadalupito (Moche IV).

Table 4. Results of the statistical comparisons of the textile and hair $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (p values for Mann Whitney U test).

		Moche IV (Guadalupito) Textiles	Moche III (El Castillo) Camelid hair	Pacatnamú (probable coastal textiles)	Chancay textiles (highland textiles)
$\delta^{13}\text{C}$	Moche III (El Castillo) Textiles	.43	.002	<.001	<.001
	Moche IV (Guadalupito) Textiles	—	<.001	<.001	<.001
	Moche III (El Castillo) Camelid hair	—	—	.45	<.001
	Pacatnamú (probable coastal textiles)	—	—	—	<.001
$\delta^{15}\text{N}$	Moche III (El Castillo) Textiles	.63	.003	.94	.46
	Moche IV (Guadalupito) Textiles	—	.002	.47	.23
	Moche III (El Castillo) Camelid hair	—	—	.001	.02
	Pacatnamú (probable coastal textiles)	—	—	—	.40

Note: p -Values <.05 are indicated in boldface.

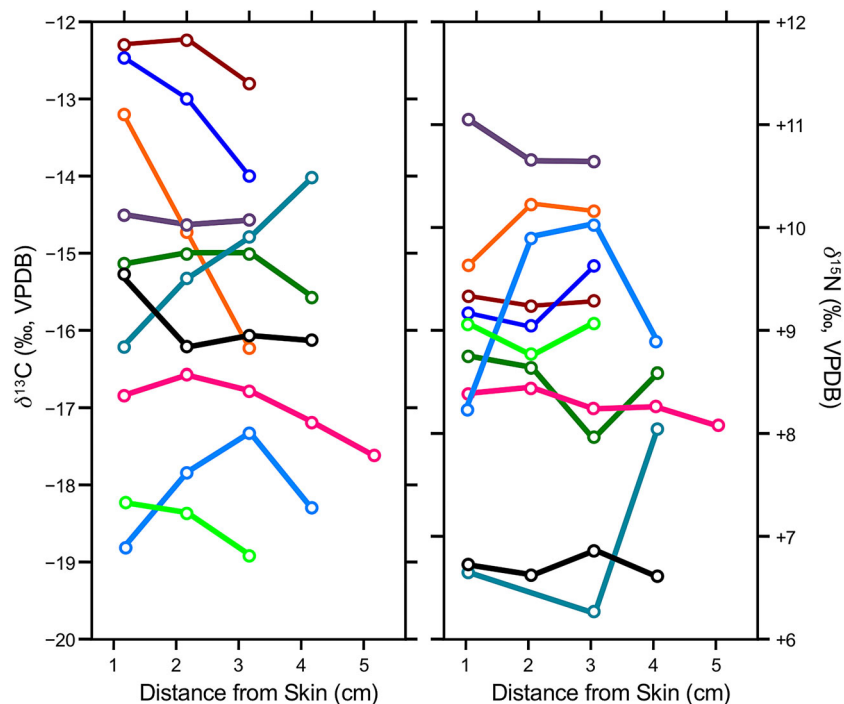
Table 5. Summary of the importance of C_4 plants in the diet and the amount of isotopic variation (SEA_c) for the samples analysed in this study and the comparative datasets.

Site(s)	Dates	Material	n	Mean % C_4 (95% CI)	SEA_c (‰ 2)	Reference
LSUCH-103 and Lsuch-145	A.D. 0–300 (Late Suchimancillo)	Collagen	5	46 (16–73)	7.4	This study
El Castillo	A.D. 300–500 (Moche III)	Collagen	38	58 (52–63)	13.7	This study
Guadalupito	A.D. 500–600 (Moche IV)	Collagen	7	51 (34–69)	19.6	This study
El Castillo	A.D. 300–500 (Moche III)	Textile	60	47 (43–51)	10.7	This study
Guadalupito	A.D. 500–600 (Moche IV)	Textile	40	43 (38–47)	7.0	This study
El Castillo	A.D. 300–500 (Moche III)	Hair	57	55 (52–59)	7.7	This study
Huaca Gallinazo (probable coastal)	A.D. 250–450	Collagen	43	48 (42–54)	10.8	Szpak et al. (2014)
Pacatnamú (probable coastal)	A.D. 1100–1320	Textile	118	58 (55–61)	8.8	Szpak et al. (2018)
Chinchawas (highland)	A.D. 500–900	Collagen	13	22 (15–29)	3.0	Szpak et al. (2015)
Chancay (highland)	A.D. 1100–1400	Textile	58	25 (22–28)	5.7	Szpak et al. (2015)

by Finucane et al. (2006) for Conchopata, but the small sample size ($n = 5$) makes it difficult to make any assertions about those data. Further analyses involving a larger number of samples are required to investigate the nature of camelid husbandry in this earlier period. Our discussion that follows is therefore limited to the Moche III and Moche IV materials.

The stable carbon and nitrogen isotope compositions for the Moche III and IV camelids were highly variable (Figure 2). The two most important variables

that distinguish camelids living in high altitude pastures from coastal or urban environments are the proportion of C_4 plants in the diet and the amount of within-group variation (Szpak et al. 2018). These two variables are depicted in Figure 5 for groups of archaeological camelids that have been analysed to date. Points plotting close to the bottom left are likely to represent highland camelids, while those plotting in the middle and towards the top and right of the plot area are more likely to represent coastal or urban camelids.

**Figure 4.** Stable carbon (left) and nitrogen (right) isotope compositions from serially-sampled camelid hair from El Castillo (Moche III).

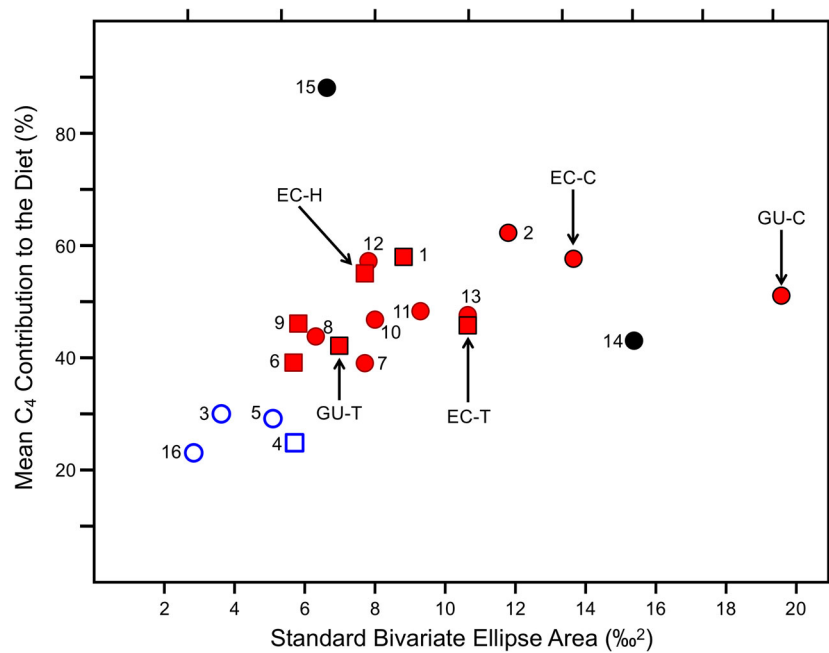


Figure 5. Plot of the standard bivariate ellipse area (x-axis) and mean estimated contribution of C_4 plants to the diet (y-axis). Circular symbols represent bone collagen and square symbols represent textiles or hair. Open symbols represent groups known or suspected to have a highland origin. Shaded symbols represent groups known or suspected to have a coastal origin. Solid black symbols (#14, 15) represent animals where the origin is uncertain or has been hypothesised to be somewhere other than the coast or highlands. Key for symbols: (EC-C) El Castillo collagen, (GU-C) Guadalupito collagen, (EC-T) El Castillo textiles, (GU-T) Guadalupito textiles, (EC-H) El Castillo hair, (1) Pacatnamú (Szapak et al. 2018), (2) Pacatnamú (Verano and DeNiro 1993), (3) Pucara (DeNiro 1988), (4) Chancay (Szapak et al. 2015), (5) Conchopata ‘alpaca’ (Finucane, Agurto, and Isbell 2006), (6) Huaca Santa Clara (Szapak et al. 2014), (7) Caylán/Humabacho (Szapak, Chicoine, et al. 2016), (8) Huancaco (Szapak, Millaire, et al. 2016), (9) Huaca Santa Clara (Szapak et al. 2015), (10) Huaca Gallinazo Early EIP (Szapak et al. 2014), (11) Huaca Gallinazo Middle EIP (Szapak et al. 2014), (12) Huaca Santa Clara LIP (Szapak et al. 2014), (13) Huaca Santa Clara Late EIP (Szapak et al. 2014), (14) Cerro Baúl (Thornton et al. 2011), (15) Conchopata ‘llama’ (Finucane, Agurto, and Isbell 2006), (16) Chinchawas (Szapak et al. 2015).

The camelids from the Santa Valley are characterised by contributions of C_4 plants and amounts of isotopic variation that are inconsistent with highland-raised animals (DeNiro 1988; Szpak et al. 2015; Thornton et al. 2011); the results are generally similar to other groups of archaeological camelids that have been interpreted as coastal residents (Dufour et al. 2014; Dufour et al. 2018; Szpak, Millaire, et al. 2016; Szpak et al. 2014). The camelid bone collagen ellipse from Guadalupito is the largest of any group analysed to date, but the area is inflated because of the small sample size for this group (Jackson et al. 2011); a probable small sample-driven inflation is also observed for Cerro Baúl ($n = 11$). The contribution of C_4 plants to the diets of the Santa Valley camelids was relatively high, especially for El Castillo (mean 58%, 95% CI 52–63%), which is a robust sample ($n = 38$). This suggests that cultivated maize was an important part of the diet, and that it was provided as fodder either in the form of grain or leaves and stems following the harvests. Such an explanation has been employed for other camelids with high $\delta^{13}C$ values (Dufour et al. 2014; Finucane, Agurto, and Isbell 2006; Goñalons and Luis 2007). The fact that the $\delta^{15}N$ values of the Santa Valley camelids are not especially high makes it unlikely that wild C_4 vegetation was a very important part of their diets.

The large amount of among-individual variation observed in the camelid bone collagen isotopic compositions at both El Castillo and Guadalupito suggests that the animals were not kept together in large herds. Large groups of animals that grazed together on the same range of foods would not be expected to have such different tissue isotopic compositions and would instead converge on a small range of similar values (Jahren and Kraft 2008). This practice of having large herds grazing on wild pastures would have been difficult if not impossible given the paucity of suitable vegetation on the coast (Rundel et al. 1991). Therefore, the type of camelid husbandry practiced was likely similar to what has been interpreted in the Virú Valley (Szapak et al. 2014), with small numbers of animals being kept in spatial isolation from one another and provisioned with a diverse range of forage, most likely agricultural products or byproducts. Even if the animals were kept as part of a small number of large herds, the isotopic data clearly demonstrate that they were managed very differently in terms of the kinds of foods that were provided to them. If these foods were brought to the camelids as fodder, it is difficult to imagine such highly differentiated diets among individuals without some manner of spatial partitioning. Because the differences were recorded in the isotopic

compositions of bone collagen, a tissue with a very slow rate of turnover (Hedges et al. 2007), this means that on average there was a large amount of *sustained* dietary variation among individuals. Thus, while the isotopic data cannot speak specifically to the size of the herds that may have been kept, there is no evidence to support the notion of large herds composed of dietary specialists (cf. Bearhop et al. 2004). Indeed, high levels of individual dietary specialisation (as reflected in isotopic variation) tend to be recorded for omnivorous or carnivorous taxa rather than large terrestrial herbivores (Bolnick et al. 2003).

The El Castillo camelid hair $\delta^{13}\text{C}$ values are virtually identical to the bone collagen $\delta^{13}\text{C}$ values after correcting for tissue-specific differences in TEF; the 95% credibility interval for C_4 plant contribution was 52–59% for hair and 52–63% for bone collagen. This is not surprising as it is expected that these two groups were derived from the same population of camelids butchered at the site. This lack of distinction does, however, support the idea that the appropriate TEF correction was applied to the hair and that the bone collagen and textile isotopic results should be directly comparable after making this adjustment. The El Castillo hair was characterised by less isotopic variation than the bone collagen, which is counterintuitive as bone collagen would be expected to be less variable because of its long turnover rate (Hedges et al. 2007), dampening any short-term variations that might be seen in hair (West et al. 2004). Even taking the mean of all of the segments for each individual and treating those values as individual samples (rather than each hair segment being treated as an individual sample) minimally changes the El Castillo hair standard ellipse area from 7.7 to 8.1 ‰², and the bone collagen ellipse is still larger in 90.0% of the comparisons between the two groups. There is, therefore, more variation among individuals reflected in the bone collagen (long-term average diet) than in the hair (short-term diet before death) at El Castillo.

On the basis of modern estimates of llama populations in the Andean highlands, annual fibre growth is ~15 cm (Frank et al. 2006). If this rate is representative of ancient llama populations, this would imply that a 1 cm segment represents slightly less than 1 month of growth (24.5 days). Most studies of fibre characteristics focus on alpacas rather than llamas as they are the primary fibre-producers today. These studies have recorded reduced growth rates in areas outside of the Andean highlands (McGregor 2002), so it is possible that if llamas or alpacas were living in the coastal river valleys, their fibre may have grown at a reduced rate (7.7–9.9 cm/year). Additionally, there is variation in fibre characteristics according to age, sex, and shearing interval (Wurzinger et al. 2006; Quispe-Peña et al. 2014). A conservative estimate of the amount of time represented by a 1 cm segment of camelid hair would therefore be 20–50 days.

There is no consistent pattern in the $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values in the serially-sampled camelid hair leading up to the time of death, although there is more pronounced temporal variation more frequently for $\delta^{13}\text{C}$ compared to $\delta^{15}\text{N}$ (Figure 4). The lack of a consistent pattern may simply be a product of different animals being slaughtered at different times of the year when particular types of fodder were more readily available. Two individuals had steadily increasing (Sample 12454 increases from –16.23 to –14.03 ‰ over four 1 cm segments) and decreasing (Sample 12408 decreases from –13.19 to –16.22 ‰ over three 1 cm segments) $\delta^{13}\text{C}$ values. These data suggest that for at least some animals, access to foods with distinct $\delta^{13}\text{C}$ values (e.g. maize or wild C_4 grasses vs. C_3 crops or *Prosopis*) was highly variable within a given year. Ultimately, incremental sampling of bioapatite from molars may provide more informative and longer-term pictures of temporal variation in camelid diets (Dufour et al. 2014).

The textile fragments at both El Castillo and Guadalupe were isotopically distinct from the highland pattern of variation observed in the Chancay textiles, with much higher contributions of C_4 plants to the diet (Figure 5). On the other hand, they were characterised by lower amounts of C_4 plants in the diet relative to the Pacatnamú textiles and the camelids (bone collagen and hair) from El Castillo and Guadalupe. There are two possibilities to explain these patterns. First, the animals used to produce wool were still local to the Santa Valley, but had different diets than the animals used to produce meat; specifically there were greater amounts of C_4 plants (likely maize) in the diets of the meat-producing animals. This scenario would make sense if both llamas and alpacas were kept in the Santa Valley with the former being used for meat (and provisioned with a greater proportion of maize) and the latter being used for wool (and provisioned with lesser amounts of maize). This pattern would approximate the one described by Finucane et al. (2006) at Conchopata, although with a less stark distinction between the two camelid groups. If both llamas and alpacas were kept in the same environment in the Santa Valley, however, there is no obvious reason why they would have been provisioned differently and we have no independent lines of evidence to make such a suggestion. Both llamas and alpacas have been raised in a great diversity of environments and appear to do well in both free-range pasture situations and confinement in dry lots with fodder being provided (Van Saun 2014; Fowler 2000; Mueller et al. 2015). Alternatively, the possibility exists that a fine-fibred variety of llama existed in the region (Wheeler, Russel, and Redden 1995) and these individuals may have been managed differently than llamas used to produce meat. This scenario does not require the presence of resident alpacas on the coast, which have a narrower

range of conditions for optimal wool production (Topic, McGreevy, and Topic 1987). Again, this is only speculative as there are no data independent of the patterns of isotopic variation to support this scenario.

A second possibility is that textiles in the Santa Valley included a mix of wools produced locally and acquired from the highlands. We have previously suggested such a scenario for the EIP occupation at Huaca Santa Clara in the Virú Valley, taking spinning and weaving styles into account (Szpak et al. 2015). If these textiles from Huaca Santa Clara are treated as one dataset, however, ignoring any internal distinctions according to manufacturing processes, they become nearly identical from an isotopic perspective relative to the textiles from El Castillo and Guadalupito. The 95% CI range for the contributions of C_4 plants to the diet for the Huaca Santa Clara textiles is 41–46% with a mean of 44%, very similar to the means of 47% for El Castillo and 43% for Guadalupito. Taking this comparison into account then, it is certainly plausible that the reason behind the isotopic distinction between textiles and hair/bone collagen at El Castillo and Guadalupito is driven by the inclusion of some imported wool. This may have been the result of a lack of availability of fine fibre derived from alpacas on the coast, which may have been more difficult to raise under these conditions than llamas (Topic, McGreevy, and Topic 1987).

Moche III/IV Transition

There was a decrease in the importance of C_4 plants in the diets of camelids between the Moche III (El Castillo) and Moche IV (Guadalupito) periods. Although this decrease was subtle, it occurred in both the bone collagen (7% reduction in the mean % C_4 contribution) and the textiles (4% reduction in the mean % C_4 contribution). Focusing on the textiles in particular, there is a much larger proportion of Moche III relative to Moche IV samples with $\delta^{13}C$ values that are higher than -15‰ (Figure 3). This shift is too subtle to be consistent with a large-scale change in the production of camelid meat and wool, as would occur with an abandonment of local camelid husbandry in the Santa Valley and the exclusive reliance on imported meat and wool from the highlands through trade. The ability to produce sufficient numbers of camelids to meet the demand of the growing Moche population may not have been possible given the limited wild vegetation available on the coast. The potential agricultural productivity of the Santa Valley is, however, tremendous due to the discharge volume of the river (Wilson 1983). If agricultural products or byproducts derived from irrigated fields were the main source of food for camelids, it seems unlikely that fodder production was the limiting factor. The demand for imported

wool from the highlands may have been driven by quality, with the high altitude pasturelands apparently producing the best wool, especially for alpacas (Topic, McGreevy, and Topic 1987). This increase in the incorporation of imported wool into the economy of the lower Santa Valley may have caused the average $\delta^{13}C$ values to be slightly lower in Moche IV relative to Moche III. Conversely, maize may have been cultivated less extensively after this transition and was therefore less readily available as camelid fodder, although there are no independent data to support this assertion. To the contrary, irrigation networks expanded considerably in the lower and middle Santa Valley during Moche IV, consistent with increased agricultural output (Chapdelaine 2010). Nonetheless, isotopic analyses of human skeletal material from the Santa Valley from each of these two periods would aid in clarifying the issue of the relative importance of maize. Despite this subtle difference between Moche III and IV camelids and textiles, the overall picture is one of stability, rather than radical change. The Santa Valley is a good example of a Southern Moche expansionist state establishing direct control during Phase IV after the integration of local groups into an economic system during the Moche III phase. In the course of these sociopolitical changes, the camelid economy was not significantly altered and the Moche, the new rulers, may have displaced the local groups in the Middle and Upper Santa Valley while maintaining the local elites and the exchange system between the rulers and the ruled.

Summary and Conclusion

Based on the stable carbon and nitrogen isotope compositions of camelid bone collagen, hair, and wool sampled from textiles, localised camelid husbandry was practiced in the Santa Valley from at least the Moche III phase (A.D. 300–500). It is not possible at this time to assess whether or not this practice was already established earlier than Moche III. The nature of camelid husbandry in the Santa Valley appears to have been very similar to that described for the Virú Valley during the EIP and LIP with animals being kept spatially segregated and fed a diverse range of fodder. Further investigation is required to determine when this form of camelid husbandry arose and its spatial extent along the coast of Perú.

The wool that was used in the manufacture of textiles appears to have been derived from the local population of camelids and was not acquired from the highlands. This is not to suggest that there was no inclusion of traded wool, but that if it was present, it was of only minor importance relative to the locally produced wool. The transition from Moche III to Moche IV, which saw a significant increase in Mochica presence in the Santa Valley, was not accompanied by a

significant change in camelid husbandry practices. Localised camelid husbandry continued largely unchanged through this cultural transition as well as through the prolonged droughts of the sixth century A.D.

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