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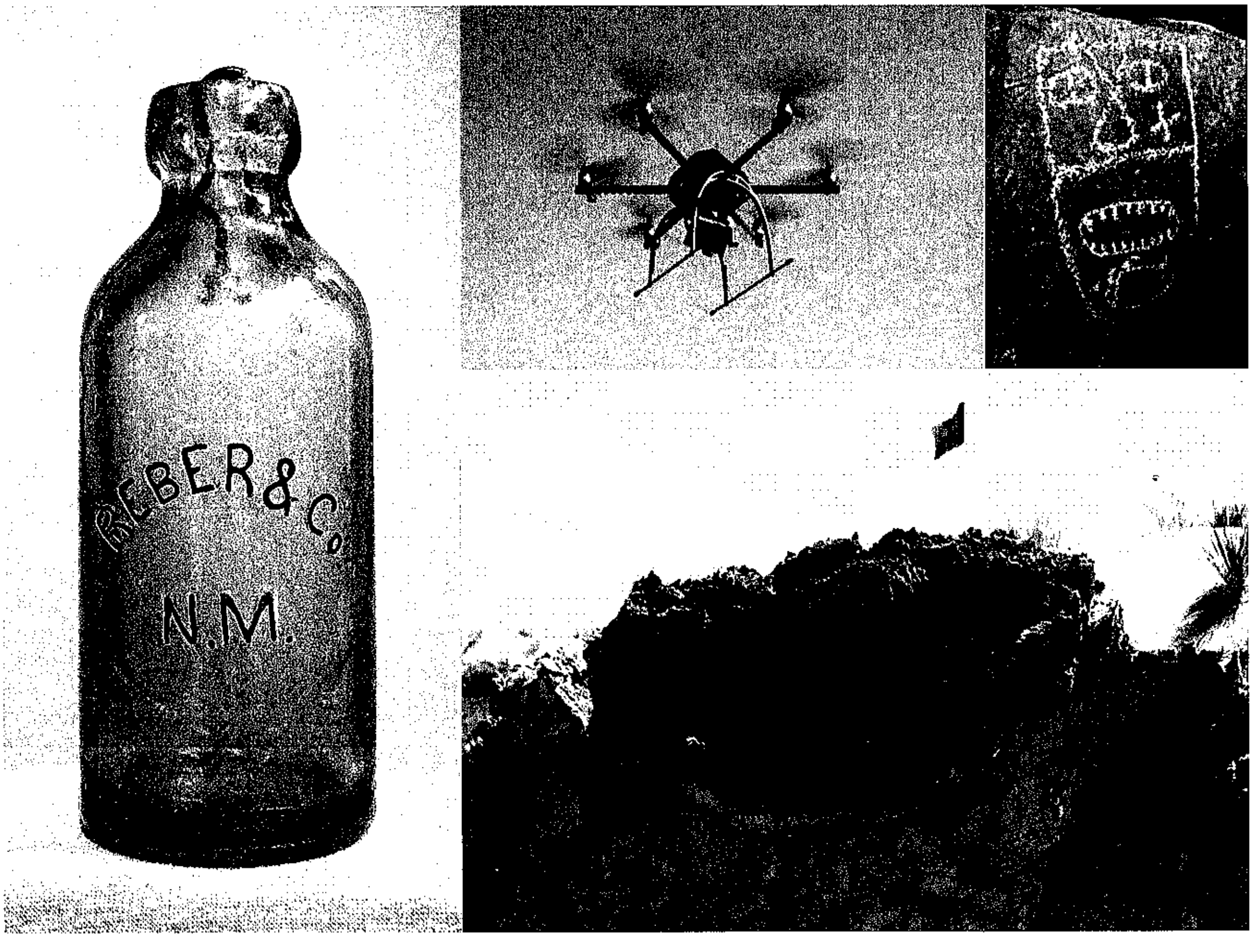

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Preliminary Results of the Stable Carbon Isotope Analysis of Modern and Prehistoric Leporid Remains from the Tularosa Basin

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Despite a history of intensive archaeological investigations in the Tularosa Basin of southern New Mexico and west Texas, paleoenvironmental studies still lack sufficient data to address detailed questions of environmental stability and change critical for modeling human adaptation (Abbott et al. 2009). Current paleoenvironmental models for the region tend to be "unidirectional" (Abbott et al. 2009) and are often based on proxy data that reflect ecological conditions at variable or unknown temporal and spatial scales. These data sets include shifts in pollen frequencies (e.g., Freeman 1972; Horowitz et al. 1981) and stable isotopes in soils that may reflect regional changes operating at hundreds of years (Monger 1993). These and other studies (e.g. Mauldin 1997; Van Devender 1990) have proven useful in building general models of long term environmental and ecological shifts that impact human adaptive success. However, these models are not designed to provide high-resolution temporal and spatial data in specific archaeological contexts. For example, modern climate and ecological data from the Tularosa basin suggests that highly localized and temporally variable precipitation events during the late spring and summer months contribute to discrete, localized pulses of plant and animal production (e.g. Gilstrap-Laslei and Ludwig 1985; Kemp 1983; Piper and Herbel 1982; Whitford 1976). If similar pulses were characteristic of the prehistoric ecology, then it is likely that production would be highly variable and site specific within the basin. Prehistoric hunter- gatherers and agriculturalists would be expected to respond to these local pulses that happen at scales of weeks or months, rather than to shifts that operate at a regional scale over centuries.

Here we present a study of stable carbon ($\delta\ ^{13}C$) isotopes in bone collagen from leporids, specifically *Lepus californicus* (black-tailed jackrabbit) and *Sylvilagus sp.* (cottontail), that begins to develop high-resolution ecological proxies that should prove useful for modeling human adaptation at smaller temporal and spatial scales in the Tularosa Basin of southern New Mexico and west Texas. Using carbon isotope results from 18 modern leporid samples collected in the Basin in 2009 and 48 prehistoric leporid samples collected from three archaeological sites that date from AD 600 to AD 1350, we demonstrate isotopic patterns consistent with dramatic shifts in vegetation over time. In addition, the prehistoric material shows increasing variability over time. While additional samples are clearly needed, these preliminary results demonstrate the potential for this type of analysis for high-resolution ecological reconstruction in Jornada archaeology.

BACKGROUND

The stable isotope analysis of bone is based on the twofold process of plant photosynthesis and ingestion/incorporation of plant $\delta^{13}C$ by animals. Plants use one of three photosynthetic pathways, designated as C_3, C_4, and CAM, to incorporate atmospheric CO_2 into plant tissue. In the case of two of these pathways (C_3 and C_4), the incorporation produces distinct $\delta^{13}C$ signatures that are subsequently incorporated, with an additional fractionation or shift, into animal tissues, including bone (Ehleringer et al. 1997; Farquhar et al. 1989; Huebner and Boutton 1994; Sharp 2007). C_3 plants are the most common plant types. All trees, and most shrubs and cool season grasses use the C_3 pathway (Ehleringer 1989; O'Leary 1981; Pate 1994; Waller and Lewis 1979). These plants have adapted to moist, colder and less sunny environments. The C_3 process or Calvin-cycle photosynthetic pathway, discriminates against atmospheric CO_2, resulting in more negative $\delta^{13}C$ signatures (Ehleringer et al. 1997; Farquhar et al. 1989; Sharp 2007). The δ^{13}C values for C_3 plants generally range from -35.0‰ to -20.0‰ with an average of about -26.0‰ (Ehleringer et al. 1997; Farquhar et al. 1989; Sharp 2007). C_4 plants, which include warm season grasses, are well adapted to and likely to be found in habitats with high daytime temperatures and intense sunlight (Ehleringer 1989; O'Leary 1981; Pate 1994; Waller and Lewis 1979). These plants use the Hatch-Slack pathway that reduces CO_2 into four-carbon acids resulting in a higher, or more positive, δ^{13}C signature (Ehleringer et al. 1997; Farquhar et al. 1989; Sharp 2007). The δ^{13}C values for C_4 plants range from approximately -16.0‰ to -7.0‰ with an average of about -12.0‰ (Ehleringer et al. 1997; Farquhar et al. 1989; Sharp 2007). Crassulacean acid metabolic (CAM) plants are adapted to conditions of high daytime temperatures, intense sunlight, and low soil moisture (Ehleringer 1989; O'Leary 1981; Pate 1994). In some cases, their metabolic pathway alternates daily between the C_3 and C_4 cycles (Ehleringer 1989; O'Leary 1981; Pate 1994). They are the least common of the three plant types, and consist primarily of cacti and agaves. In the southern American Southwest, the carbon isotopic signature of CAM plants is similar to those of C_4 plants.

The carbon isotopic signature of an animal reflects the isotopic signatures of the food consumed by that animal throughout much of its lifetime (Ambrose and Norr 1992; DeNiro and Epstein 1978). In addition, archaeological and paleontological researchers have used isotopic studies of herbivores to reconstruct aspects of past environments by focusing on types of plant that were in their diet (Ambrose and Krigbaum 2003; Ehleringer et al. 1997; Hedges et al. 2004; Huebner and Boutton 1994; Iacumin et al. 2000; Koch et al. 2004). For example, previous studies (Chisholm et al. 1986; Huebner 1991; Huebner and Boutton 1994; Land et al. 1980) have shown that deer and bison in Texas have distinct δ^{13}C signatures based on their diets that emphasize either C_3 shrubs (deer) or C_4 grasses (bison). Critical to our investigations are herbivores that consume both C_3 and C_4 plants. This subsistence pattern would potentially reflect both dominant plant types within an environment and possibly shifts in dominance in plant communities over time (see Mauldin 1993; Rogers and Wang 2002; Smith et al. 2002).

Jackrabbits and cottontails are short-lived with an estimated lifespan of approximately two to three years in the wild (see Feldhammer 1979; French et al. 1965; Smith 1990). They are found in a variety of environments including open grasslands, farmlands, and deserts and are one of the most common species in the western United States (Davis and Schmidly 1994). These leporids have a limited home range of about 1 km² in size, although home range size will vary dependent upon habitat quality (Davis and Schmidly 1994; French et al. 1965; Smith 1990). They consume a broad spectrum of vegetation that includes grasses, shrubs and forbs (Daniel et al. 1993; Flinders and Hansen 1972), and their diets shift as vegetation changes over the course of a year (Chapman et al. 1982; Currie and Goodwin 1966; Hayden 1966; Vorhies and Taylor 1933; Westoby 1980). Given their limited home range size, their diet should reflect local vegetation signatures. Based upon these characteristics, leporids appear to be well suited to serve as a high-resolution proxy for studies of paleovegetation. Previous studies of leporid diet through stable carbon isotopic signatures support this observation (see Kemp et al 2011; Mauldin 1993; Munoz et al. 2011; Smith et al. 2012).

SAMPLE SELECTION AND METHODS

To assess the utility of small herbivores as indicators of paleovegetation within the Tularosa basin, we used both modern and prehistoric leporid samples. As shown in Figure 1, the modern samples, consisting of 10 cottontails and 8 jackrabbits, were collected from the central basin in the late winter and early spring of 2009. The archaeological samples come from three sites, the Conejo Site (LA 91044), the Meyer Pithouse Village (LA 97128), and Madera Quemada Pueblo (LA 91220). All three of the sites are at the margins of the Tularosa Basin in alluvial fan settings (Figure 1), and date to the Formative Period (A.D. 200–A.D. 1450) of the Jornada Mogollon (see Miller and Kenmotsu 2004). This period is characterized by an architectural transition from pithouses to pueblos, the gradual adaptation of agriculture, and changes in settlement patterns. Table 1 lists the sites by name, description, time frame and the number of samples of each species.

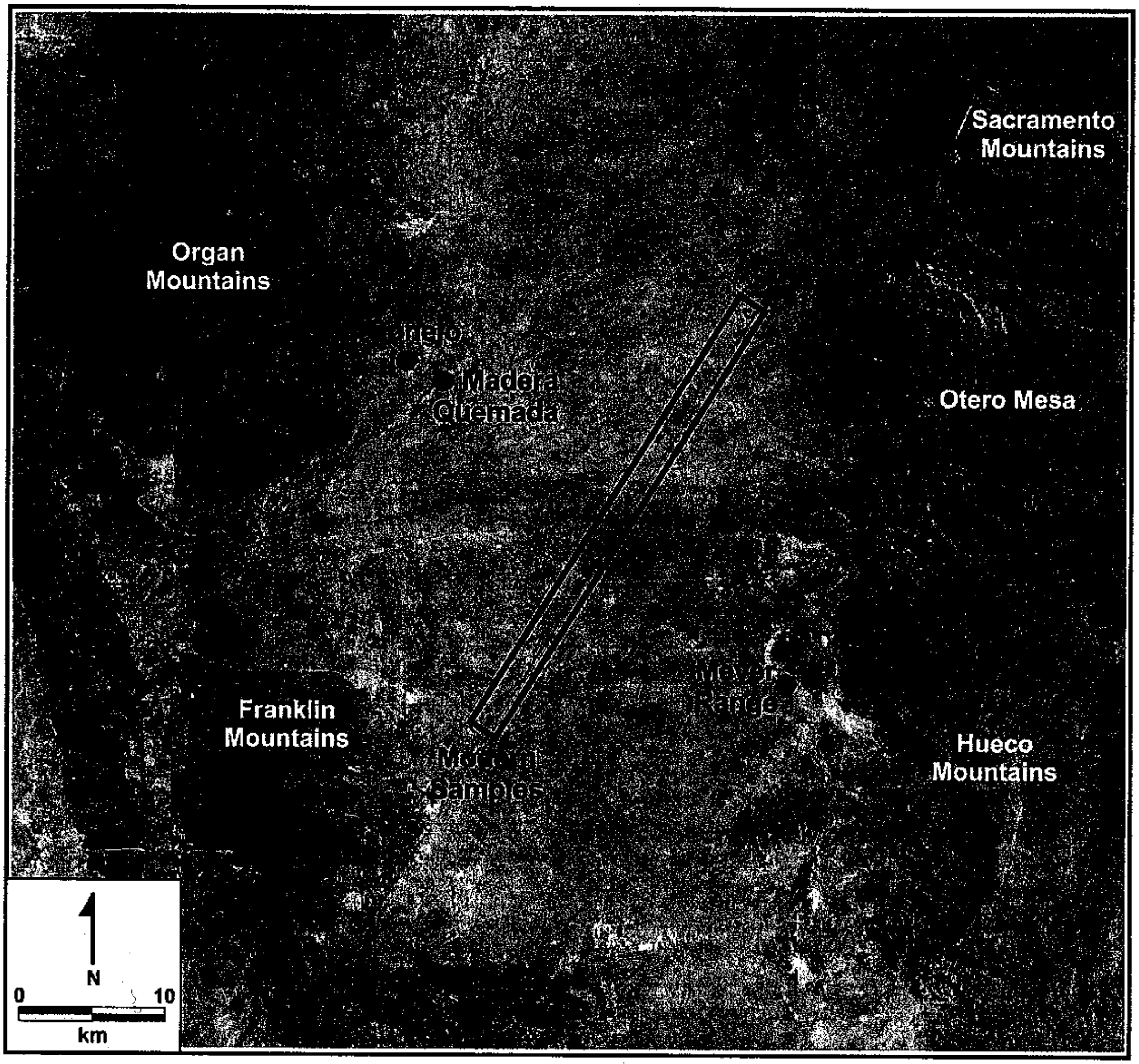

Figure 1. The study area showing the location of modern sample collection and archaeological sites.

Table 1. Prehistoric Site Descriptions.

Name	Description	Date	Number of *Lepus* Specimens	Number of *Sylvilagus* Specimens
Conejo Site[1]	Mesilla Phase village	A.D. 600-900	10	7
Meyer Pithouse Village [2]	Late Dona village	A.D. 1150-1200	8	6
Madera Quemada[3]	El Paso Phase 13-room pueblo	A.D. 1300-1350	10	7

[1]Miller and Burt 2007; [2]Scarborough 2001; [3]Miller and Graves 2009

Preparation and Analysis of Leporid Bone Collagen

ere prepared at the Center for Archaeological Research at the University of Texas at San Antonio llowing tested procedures to extract bone collagen (see Munoz et al. 2011). The samples were first foreign material. The bone was then lightly crushed, followed by sonication in ultra-pure water. A 100 to 200 mg of bone was then decalcified in 0.5N HCl under refrigeration for 30 hours (Ambrose Bocherens et al. 1991; DeNiro and Epstein 1981; Longin 1971). This treatment removed all acid-nces. The samples were then washed repeatedly in ultra-pure water, after which they were treated OH for 45 minutes to remove humic acids and some lipids. The samples were then repeatedly washed re water until yielding a neutral pH. The resulting residue was solubilized with 0.01N HCl at 70°C for closed glass test tubes. The solubilized mixture was then frozen and subsequently freeze-dried, collagen. Collagen samples were then weighed into tin cups in preparation for the isotopic analysis.

es were analyzed by the Northern Arizona University (NAU) Colorado Plateau Stable Isotope Laboratory. ECS4010 Elemental Analyzer on-line with a DELTA V Advantage mass spectrometer configured through a for automated continuous-flow analysis (Colorado Plateau Stable Isotope Laboratory 2009) was used to the carbon and nitrogen isotope compositions, along with the percentage of C and N in collagen to yield atio. The preservation of bone collagen is a significant issue within isotopic studies as bone undergoes mortem processes or diagenesis that changes and degrades its chemical composition (DeNiro 1985). A rived from the atomic weight of carbon to nitrogen (C/N) in a sample, is calculated to assess diagenetic and collagen degradation. A sample with a carbon to nitrogen ratio of between 2.9 and 3.6 suggests that llagen has not undergone significant diagenetic alterations and is a valid sample (DeNiro 1985).

able isotope ratio of bone collagen was measured in a mass spectrometer and measured against the carbon ard known as the Vienna PeeDee Belemnite (VPDB). This standard is assigned a $\delta^{13}C$ value of 0‰ (Ehleringer 1997; Farquhar et al. 1989; Sharp 2007). The difference between the sample and the standard is known as lative ^{13}C content, designated by δ (delta). The $\delta^{13}C$ of a sample is given by the equation:

$$\delta^{13}C = \left[\frac{(^{13}C/^{12}C)_{\text{sample}}}{(^{13}C/^{12}C)_{\text{standard}}} - 1 \right] \times 1000‰$$

otopic data generated during this study were normalized using international standards obtained from the rnational Atomic Energy Agency and the National Institute of Standards and Technology. Analytical precision the NAU Colorado Plateau Stable Isotope Laboratory is ± 0.10‰ or better for $\delta^{13}C$ and ± 0.20‰ or better for N.

RESULTS

All 18 modern samples produced usable collagen, as did 50 of the 61 prehistoric samples. These 68 samples with results are listed in Table 2. Forty-eight of the 50 prehistoric samples and all 18 of the modern samples had atomic C/N ratios within acceptable limits, suggesting that the collagen was sufficiently intact to provide accurate dietary information. As shown in Table 2, prehistoric jackrabbit specimens with good C/N ratios exhibit $\delta^{13}C$ values ranging from -17.5‰ to -9.3‰ (n=28) with a median value of -13.85‰. Cottontail rabbits with good C/N ratios (n=20) had $\delta^{13}C$ values ranging from -21.6‰ to -11.3‰ with a median value of -14.3‰. The slight preference for consumption of C_3 over C_4/CAM plants shown by these values in cottontails relative to jackrabbits in the prehistoric sample is also present in the modern samples. The $\delta^{13}C$ values for modern jackrabbit specimens from the Tularosa Basin (n=8) ranged from -20.0‰ to -15.8‰, while cottontails (n=10) had values ranging from -21.1‰ to -16.2‰. This slight difference in consumption probably reflects available vegetation within a habitat as cottontails are often found in areas with more ground cover (Brown 1947; Chapman et al. 1982; Vorhies and Taylor 1933). These areas also tend to have more C_3 vegetation.

Figure 2 presents boxplots of the $\delta^{13}C$ values, grouped by age/location, for the 36 modern and prehistoric jackrabbits with good C/N ratios. The medians for the $\delta^{13}C$ collagen values at each of the prehistoric sites are roughly similar, hovering between -14.5‰ and -13.8‰, suggesting roughly similar diets dominated by consumption of C_4/CAM species. The interquartile ranges are also roughly similar in values, though the samples from Madera Quemada are both more dispersed and are trending towards values that are more C_3 in character. The modern pattern for jackrabbits is distinct from these prehistoric patterns (Figure 2). Both the median $\delta^{13}C$ value for the modern samples of -18.1‰, as well as the interquartile range that falls between -17.1‰ and -19.8‰, show a strong C_3 pattern. Figure 3 presents boxplots of the $\delta^{13}C$ values for the 30 cottontails with good C/N ratios grouped by location/age (Table 2). As with the jackrabbit collagen values in Figure 2, the carbon isotopic values for the three prehistoric sites show a C_4/CAM dietary pattern, with median values ranging between -14.5‰ and -13.0‰. As with the Figure 2 pattern, the interquartile ranges also reflect C_4/CAM vegetation, with indications of a movement towards C_3 vegetation at Madera Quemada around A.D. 1300–1350. Finally, as with the pattern in jackrabbit collagen, the median $\delta^{13}C$ value for the modern samples (-19.6‰), as well as the interquartile range that falls between -18.5‰ and -19.9‰ (Figure 3), indicates a strong C_3 cottontail diet.

The shift evident in $\delta^{13}C$ values from a C_4/CAM dietary pattern during the prehistoric sequence to one dominated by C_3 plants in the modern period occurs in both species. This shift in bone collagen is approximately 4.3‰ in jackrabbits and 6.6‰ in cottontails. Assuming a depletion of about 1.2‰ in atmospheric carbon values because of the burning of fossil fuels (Nelson 2007), this shift in collagen carbon values is still roughly 3‰ for jackrabbits and 5.4‰ for cottontails. These patterns clearly suggest that the underlying vegetation structure shifted, which may reflect vegetation changes related to land use, climate change, or sampling locations. Differences caused by sampling locations may reflect the shift from alluvial fans to more open central basin geographic locations. Figure 1 shows that the archaeological samples are all from sites on alluvial fans. In contrast, the modern samples were collected from the central basin, a region currently dominated by mesquite and other C_3 shrubs. While alluvial fans also have high frequencies of shrubs, these settings tend to have higher frequencies of C_4 grass and CAM plants. The differences we see in Figures 2 and 3 could simply reflect these different landforms. We are processing additional sites from the basin that should allow us to address this possibility in the future.

While we cannot rule out the influence of sampling different landforms, the expansion of C_3 shrubs and the reduction of grasslands suggested by Figures 2 and 3 are consistent with historic accounts of vegetation changes in the region. Changes in land use practices, including fire suppression and ranching associated with European settlement in the 1800s are often suggested as causes for these well-documented vegetation shifts (see Dick-Peddie 1993; Harris 1966; York and Dick-Peddie 1969). However, our results suggest that these shifts in vegetation may have begun well before European settlement, with hints present in the leporid samples from Madera Quemada. While additional data sets are clearly needed to confirm these patterns, the possible onset of this shift in the fourteenth century suggests that a climate component may also be present.

Figure 4 provides additional data on the prehistoric sequence and a possible climate component to the vegetation shifts by considering two measures of variability. The upper graph in the figure shows the range of isotopic values for *Lepus* and *Sylvilagus* for the three sites. The lower graph presents the coefficient of variation [(standard deviation/mean)*100] for these same data sets. Both graphs show roughly the same pattern with increasing variability through time. These patterns are not a function of sample size differences, nor do they seem to pattern with occupation lengths as the two shortest occupations, at Madera Quemada and Meyer, have the highest variation. A remaining possibility is that the increasing variability through time in the isotopic values reflects higher year-to-year variability in vegetation structure, perhaps as a function of a more variable climate. If this possibility is accurate, it would have significant implications for prehistoric populations in the region.

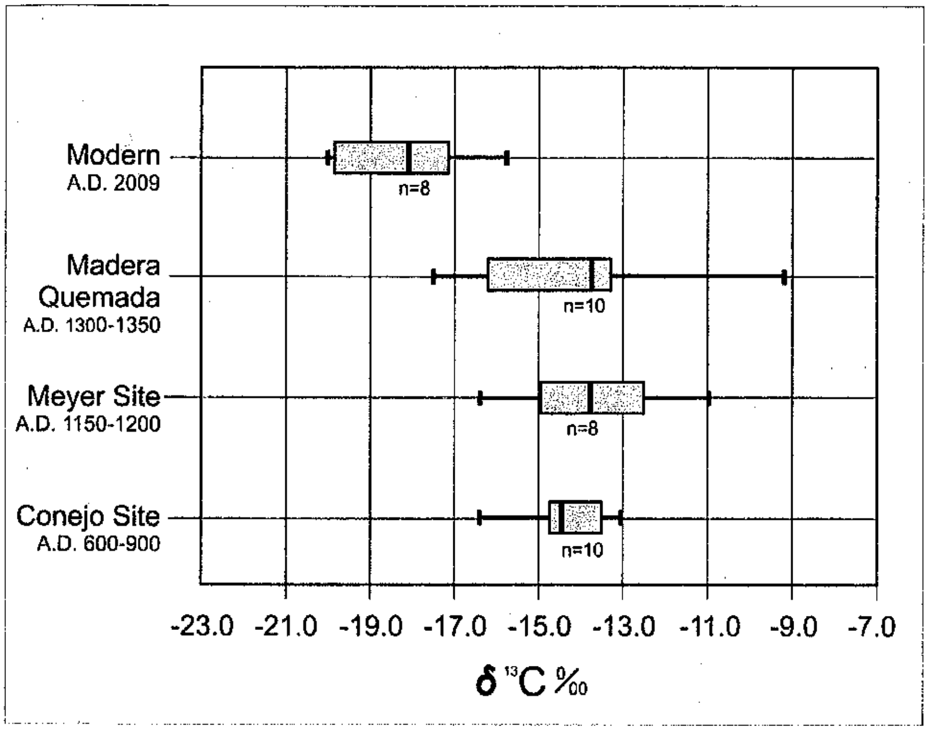

Figure 2. Boxplots of Lepus δ^{13}C values.

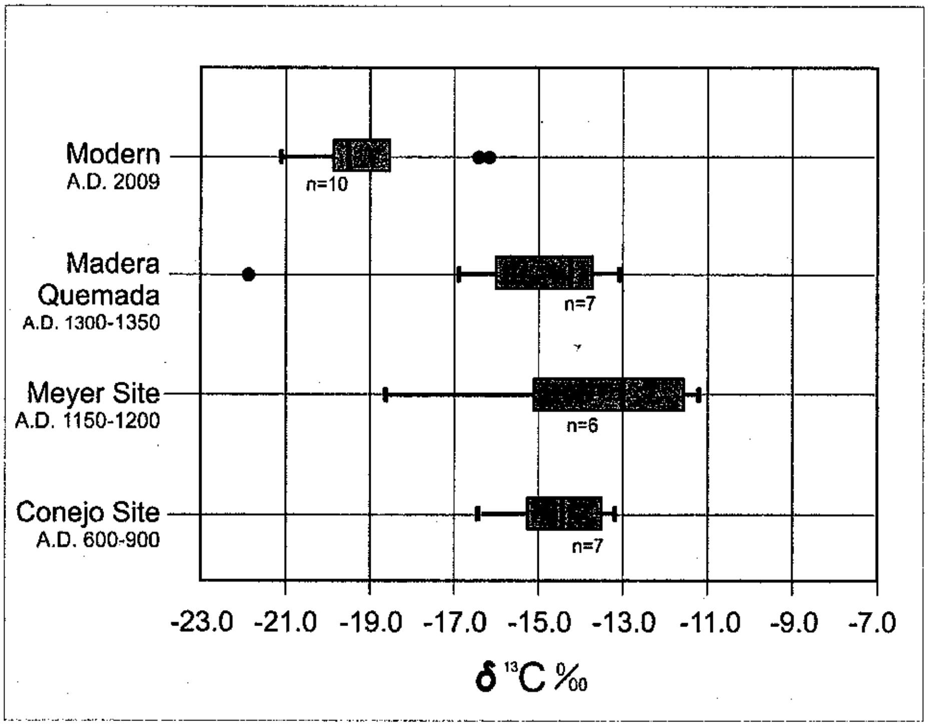

Figure 3. Boxplots of Sylvilagus δ^{13}C values.

Table 2. Stable Carbon and Nitrogen Isotopic Data for Modern and Prehistoric Leporids from the Tularosa Basin.

CAR ID	Genus	Location	Date (BC/AD)	Phase	C/N ratio (atomic)	δ^{15}N AIR	N%	δ^{13}C PDB collagen	C%
L234	*Lepus*	Central Basin	Modern	N/A	3.31	6.1	15.96	-17.3	45.27
L235	*Lepus*	Central Basin	Modern	N/A	3.21	11.1	15.74	-15.8	43.36
L236	*Lepus*	Central Basin	Modern	N/A	3.21	5.6	16.26	-17.2	44.75
L237	*Lepus*	Central Basin	Modern	N/A	3.29	6.3	15.73	-18.9	44.30
L238	*Lepus*	Central Basin	Modern	N/A	3.27	7.0	15.43	-19.7	43.21
L239	*Lepus*	Central Basin	Modern	N/A	3.29	8.9	15.41	-20.0	43.45
L240	*Lepus*	Central Basin	Modern	N/A	3.30	8.7	15.76	-20.0	44.57
L241	*Lepus*	Central Basin	Modern	N/A	3.29	6.7	14.06	-17.1	39.65
S83	*Sylvilagus*	Central Basin	Modern	N/A	3.39	6.1	13.59	-19.5	39.45
S85	*Sylvilagus*	Central Basin	Modern	N/A	3.39	6.5	12.21	-18.9	35.50
S86	*Sylvilagus*	Central Basin	Modern	N/A	3.32	7.0	13.85	-19.9	39.47
S87	*Sylvilagus*	Central Basin	Modern	N/A	3.31	5.8	14.18	-21.1	40.26
S88	*Sylvilagus*	Central Basin	Modern	N/A	3.28	5.7	14.51	-16.4	40.80
S89	*Sylvilagus*	Central Basin	Modern	N/A	3.31	5.5	14.82	-20.0	42.11
S90	*Sylvilagus*	Central Basin	Modern	N/A	3.29	6.6	15.11	-19.7	42.65
S91	*Sylvilagus*	Central Basin	Modern	N/A	3.31	5.7	14.76	-19.8	41.92
S92	*Sylvilagus*	Central Basin	Modern	N/A	3.25	6.0	15.11	-18.5	42.17
S93	*Sylvilagus*	Central Basin	Modern	N/A	3.34	5.9	14.41	-16.2	41.33
L299	*Lepus*	Conejo	AD 600-900	Mesilla	3.38	8.0	13.62	-13.4	39.43
L300	*Lepus*	Conejo	AD 600-900	Mesilla	3.36	8.8	13.84	-16.4	39.86
L301	*Lepus*	Conejo	AD 600-900	Mesilla	3.31	9.1	14.24	-14.8	40.46
L302	*Lepus*	Conejo	AD 600-900	Mesilla	3.34	8.6	13.36	-14.8	38.28
L303	*Lepus*	Conejo	AD 600-900	Mesilla	3.45	8.8	11.66	-14.6	34.47
L304	*Lepus*	Conejo	AD 600-900	Mesilla	3.42	7.0	12.72	-15.5	37.28
L305	*Lepus*	Conejo	AD 600-900	Mesilla	**4.32***	6.5	6.29	-18.5	23.27
L307	*Lepus*	Conejo	AD 600-900	Mesilla	3.44	7.8	11.37	-13.6	33.55
L308	*Lepus*	Conejo	AD 600-900	Mesilla	3.44	7.3	10.93	-13.7	32.25
L309	*Lepus*	Conejo	AD 600-900	Mesilla	3.38	8.4	13.25	-13.1	38.36
L310	*Lepus*	Conejo	AD 600-900	Mesilla	3.44	6.4	13.00	-14.4	38.38
S226	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.35	8.8	13.86	-14.9	39.88
S228	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.40	7.6	12.07	-16.4	35.24
S229	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.64	7.1	12.60	-16.1	39.31
S231	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.51	5.9	11.47	-13.5	34.53
S232	*Sylvilagus*	Conejo	AD 600-900	Mesilla	**3.60***	7.6	12.02	-15.8	37.07
S233	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.46	6.7	12.09	-13.5	35.85
S234	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.37	7.8	14.12	-13.2	40.80
S235	*Sylvilagus*	Conejo	AD 600-900	Mesilla	3.44	5.8	12.61	-14.5	37.22
L312	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.37	7.4	13.18	-14.6	38.06
L313	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.50	11.4	11.86	-9.3	35.54
L314	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.39	7.4	13.13	-17.3	38.22
L315	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.38	7.4	11.71	-13.4	33.93

CAR ID	Genus	Location	Date (BC/AD)	Phase	C/N ratio (atomic)	δ^{15}N AIR	N%	δ^{13}C PDB collagen	C%
L316	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.36	6.0	12.74	-16.2	36.71
L318	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.39	5.9	12.79	-14.0	37.21
L319	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.38	5.9	12.78	-13.6	37.02
L320	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.35	6.6	12.92	-13.4	37.15
L321	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.30	5.9	14.08	-17.5	39.90
L322	*Lepus*	Madera Quemada	AD 1300-1350	El Paso	3.31	5.2	14.58	-13.0	41.43
S238	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.43	5.9	13.42	-21.6	39.46
S241	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.39	6.3	13.70	-14.3	39.79
S242	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.38	7.0	13.68	-15.0	39.66
S243	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.47	7.3	12.42	-14.3	36.90
S246	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.38	9.6	12.76	-16.9	36.98
S248	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.40	7.0	13.09	-13.1	38.18
S250	*Sylvilagus*	Madera Quemada	AD 1300-1350	El Paso	3.33	5.6	14.12	-13.3	40.32
L306	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.35	6.7	14.10	-13.8	40.47
L326	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.37	7.0	13.74	-16.0	39.73
L329	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.40	6.2	12.88	-13.8	37.60
L332	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.34	6.3	13.49	-11.4	38.66
L333	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.38	6.5	13.11	-16.4	38.04
L334	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.37	8.7	13.90	-11.0	40.12
L336	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.44	7.1	13.72	-13.9	40.51
L337	*Lepus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.40	6.9	13.33	-13.8	38.84
S237	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.40	5.6	14.33	-18.7	41.80
S251	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.39	7.6	13.75	-14.2	40.00
S252	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.43	5.3	13.14	-11.3	38.64
S254	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.41	6.1	12.92	-11.6	37.82
S257	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.38	7.2	13.30	-15.3	38.58
S258	*Sylvilagus*	Meyer Pithouse Village	AD 1150-1200	Late Dona Ana	3.39	5.9	12.73	-11.8	36.96

*C/N ratios outside of acceptable range.

CONCLUSIONS

Our preliminary results suggest that stable isotopic research on leporid collagen can provide high-resolution ecological reconstructions in a variety of contexts. Their isotopic signatures can provide site-specific vegetation reconstructions. This level of analysis is not commonly available from other data sets, such as packrat middens or tree-ring samples, which are restricted to specific settings or periods. In contrast, leporids are ubiquitous on archaeological sites in the Jornada region. Their use as a vegetation proxy can complement our existing paleoenvironmental knowledge in the region, and provide critical data to refine our understanding of human adaptation to climate variability within arid environments.

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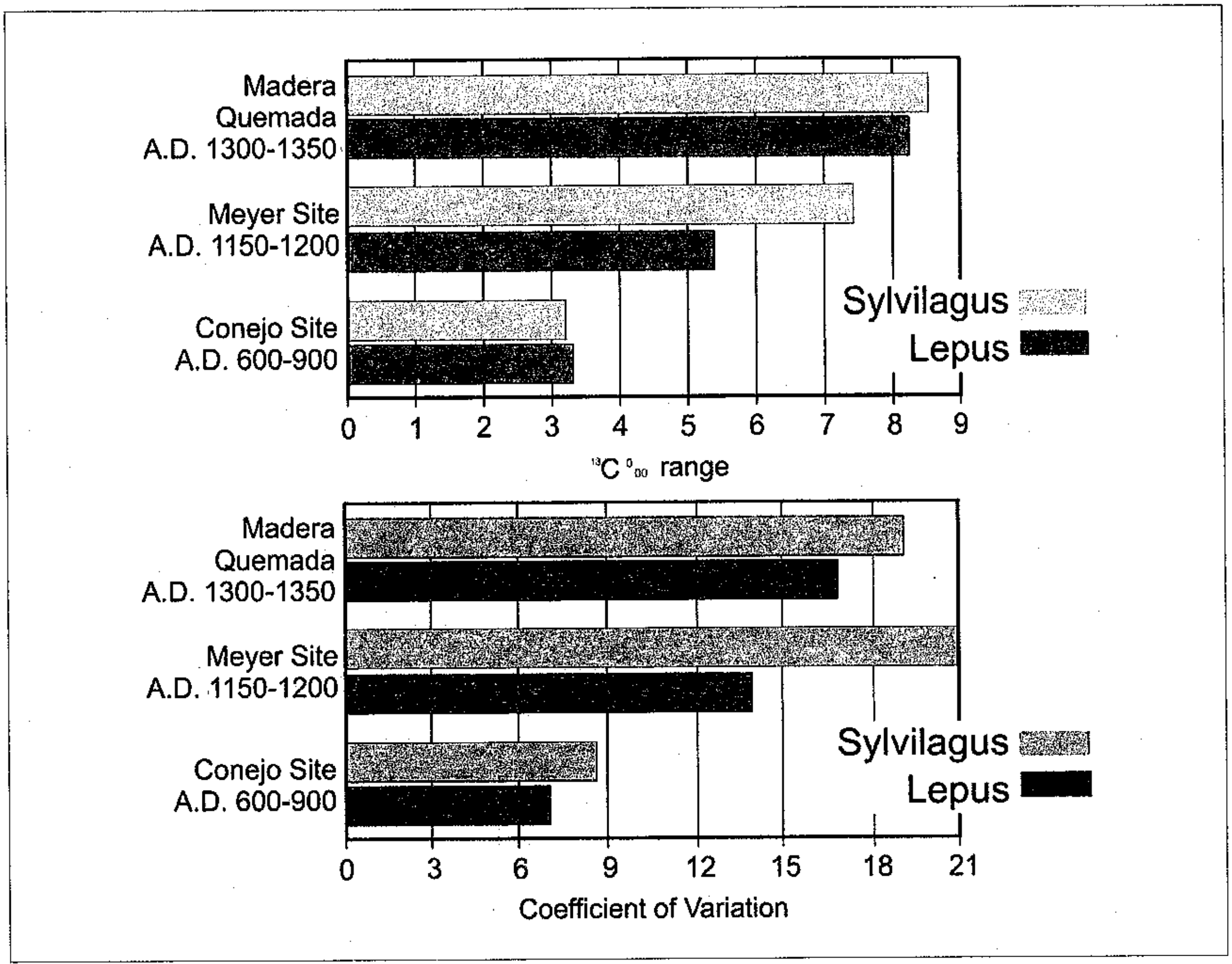

Figure 4. Measures of variability seen in both species through time.

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