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The pilgrimage economy of Early Roman Jerusalem (1st century BCE–70 CE) reconstructed from the $\delta^{15}N$ and $\delta^{13}C$ values of goat and sheep remains

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ABSTRACT

Religious and historical sources suggest that pilgrimage formed a major source of Jerusalem's economy during the Early Roman period due to the Temple's role as a religious and judicial center for the Jewish diaspora. Until now, this assertion has been supported by little material evidence. In this study, the carbon and nitrogen isotope values of local arcahaeological and, modern wild herbivores from known environments were used to determine the environmental origins of domesticated sheep and goat that were traded and consumed in Early Roman Jerusalem. Pinpointing the environmental origins of these herd animals can determine if they were raised in specialized farms in the vicinity of Jerusalem, brought to the city by local pilgrims, or were part of organized importation of sacrifice animals from desert regions that lie beyond the boundaries of the province of Judea. The results indicate that at minimum 37% of the goat and sheep consumed in Jerusalem during the Early Roman period were brought from desert regions. The inter-provincial importation of animals to Jerusalem to meet high demands for sacrifice by pilgrims is the first material evidence for large scale economic specialization in the city. Furthermore, the results imply that desert animals were further marketed for domestic use in contemporaneous farm sites out of Jerusalem.

1. Introduction

During the Early Roman period—between King Herod's reign (37–4 BCE) and the destruction of Jerusalem's Temple in 70 CE—the provision of services and commodities to a large seasonal population of pilgrims is assumed to have fueled Jerusalem's economy (Goodman, 1999; Levine, 2002). During this period Jerusalem reached its peak and its temple compound served as the religious and judiciary center for the entire Jewish population. At this time Jewish communities were well established throughout the Roman Empire and the Near East far beyond the boundaries of the Province of Judea (Safrai, 1974; Applebaum, 1976a). In addition to dues and tithes sent annually by Jewish communities to support temple activities (Safrai, 1974), Jews were commanded to go on pilgrimage during the major holidays (i.e. in Hebrew *Sukkot*, *Pessah* and *Shavuot*) and to participate in sacrificial activities. Since animal sacrifice was restricted to Jerusalem's temple, pilgrimage to the city during the major holidays became a mass event. The population of Jerusalem in this period has been estimated at 30,000 people, and it is likely that these figures doubled or even tripled during the major holidays (Levine, 2002; Safrai, 1994).

Other than religious and historical sources that mostly postdate the destruction of the temple, there is little direct evidence about Jerusalem's pilgrimage economy during this important period (Safrai, 1974; Applebaum, 1976b; Amit et al., 2000; Kloner, 2000; Levine, 2002). Recent analysis of fauna from Jerusalem's dump found that goats and sheep (domestic caprids) were marketed in Early Roman period Jerusalem primarily for meat consumption, indicating that the urban population functioned as a consumer society. In the absence of other major sources of income much of the city's prosperity derived from its religious status (Bar-Oz et al., 2007). This study provides the first primary evidence for a specialized economy promoted by Jewish pilgrimage in Early Roman Jerusalem. It does so using stable isotope methods to track the origins of domestic caprids that were traded and consumed in the city.

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Several complementary scenarios can be proposed to describe the origin of the caprids that were consumed in Jerusalem during the Early Roman period. First, the local Jewish population, concentrated in small farming communities in the Mediterranean hills of Judea and the Galilee, brought their caprids directly to Jerusalem (Safrai, 1994) (Fig. 1a). Second, a specialized herding economy primarily existed in the steppic environment and rocky landscapes of Judea that are unsuitable for commercial agriculture (Safrai, 1994; Baruch, 1999). These herders may have marketed their caprids in Jerusalem. Finally, caprids were being imported from the desert regions of neighboring provinces on a large scale as suggested by a few Talmudic sources (Applebaum, 1976b; Safrai, 1994) (Fig. 2).

Large garbage deposits that accumulated during the Early Roman period, between King Herod reign and the destruction of the temple (~50 BCE–70 CE) were recently exposed on the western slopes of the Kidron Valley outside the walls of Jerusalem's old city (Reich and Shukron, 2003) (Fig. 1c) (for archaeological data collection see Supplementary Data Text 1). These deposits include a large faunal assemblage dominated by domestic caprid remains sampled here (Bouchnick et al., 2004; Bar-Oz et al., 2007).

To identify the contribution of different caprid sources to Jerusalem's economy this study builds on a previously demonstrated relationship between present day plant isotope composition ($\delta^{13}C$ and $\delta^{15}N$ values) and water availability (Stewart et al., 1995;

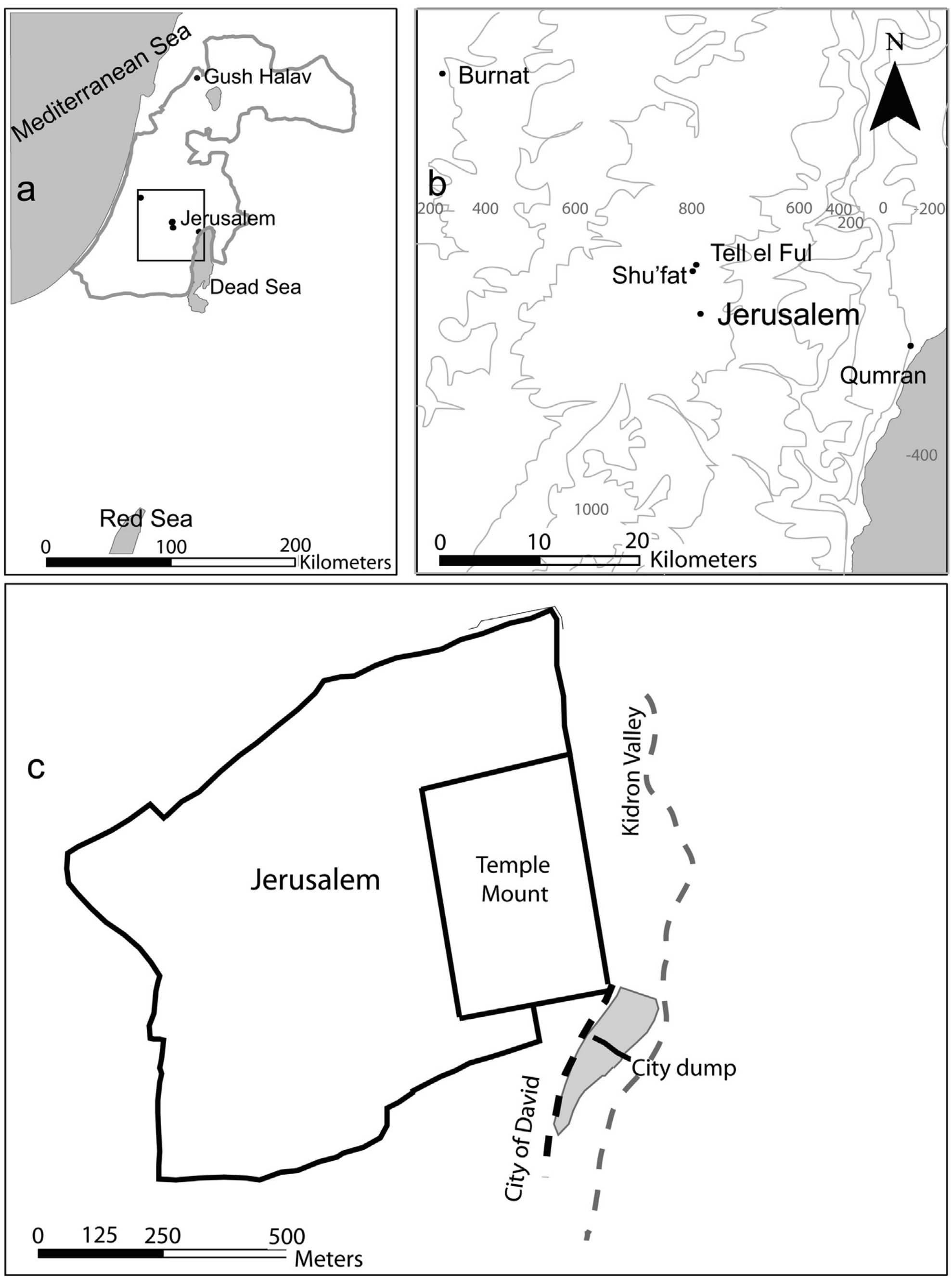

Fig. 1. Map of King Herod's kingdom and the studied sites mentioned in the text. **a**. Regional map; King Herod's client kingdom boundaries are indicated in gray; **b**. enlarged area of the sites sampled in this study; and **c**. the location of Jerusalem's city dump (gray area) in relation to the city walls and the second Temple Mount (present day outer city walls).

Handley et al., 1999; Swap et al., 2004; Hartman and Danin, 2010), and the relationship between plant isotope composition and wild primary consumers along aridity gradients (Murphy and Bowman, 2006; Hartman, 2011, 2012). This region is well suited for rainfall based environmental sourcing because of steep north-south and west-east aridity gradients with mean annual rainfall ranging from 1000 mm to less than 50 mm/year (Goldreich, 2003). Early Roman period domestic caprids from archaeological sites located in different environments are used as references that help determine the origins of Jerusalem caprids (Gush Halav, Burnat, and Qumran) (Fig. 1a,b). Modern mountain gazelles (*Gazella gazella*), Dorcas gazelles (*Gazella dorcas*) and ibexes (*Capra ibex nubiana*) from known environments are used to complement archaeological data by predicting the isotopic ranges of animals originating from different environments in the southern Levant (modern Israel, the Palestinian Authority, and the Sinai Peninsula) (Fig. 2; for data collection see Supplementary Data Text 2.). Differences between the feeding ecology of gazelles and caprids can complicate interpretations of the archeological data (Supplementary Data Text 4). Modern gazelle analogs are therefore only used to fill gaps in the archaeological record. Data from Early Roman period farm sites in the vicinity of Jerusalem (Tell el Ful, Shu'fat) are used to derive expectations for the $\delta^{13}C$ and $\delta^{15}N$ value ranges of locally grown caprids. The environmental origins of caprids from the recently discovered city dump of Jerusalem can then be determined based on their $\delta^{13}C$ and $\delta^{15}N$ values.

1.1. South Levantine environmental zones

The southern Levant is divided here into four major environments based on present mean annual rainfall (mm/yr). Mean rainfall data covering the years 1961–1990 is provided by the Israeli Meteorological Service and mapped by the Hebrew University of Jerusalem GIS center. The rainfall data is in general agreement with the phytogeographic division of the region that was originally published by Eig (1938) and later corrected (Danin and Plitmann, 1987) (Fig. 2). The Mediterranean region, is dominated by Mediterranean plant species, and can be further divided into mesic Mediterranean (≥700 mm/yr, or aridity index of >0.5) and xeric Mediterranean (<700–350 mm/yr, aridity index ranges between <0.5–0.25) zones. The steppic environments (<350–150 mm/yr, aridity index <0.25) support open landscape vegetation (Batha) dominated by dwarf shrubs. The steppe vegetation includes transitional Mediterranean, Irano-Turanian, and Saharo-Arabian plant species. Finally, the deserts (<150 mm/yr, aridity index <0.1) are primarily dominated by Saharo-Arabian species, and the hot Jordan Valley is marked by an intrusion of tropical Sudanese species (for rainfall and aridity index data see Hartman, 2012) (Danin and Plitmann, 1987).

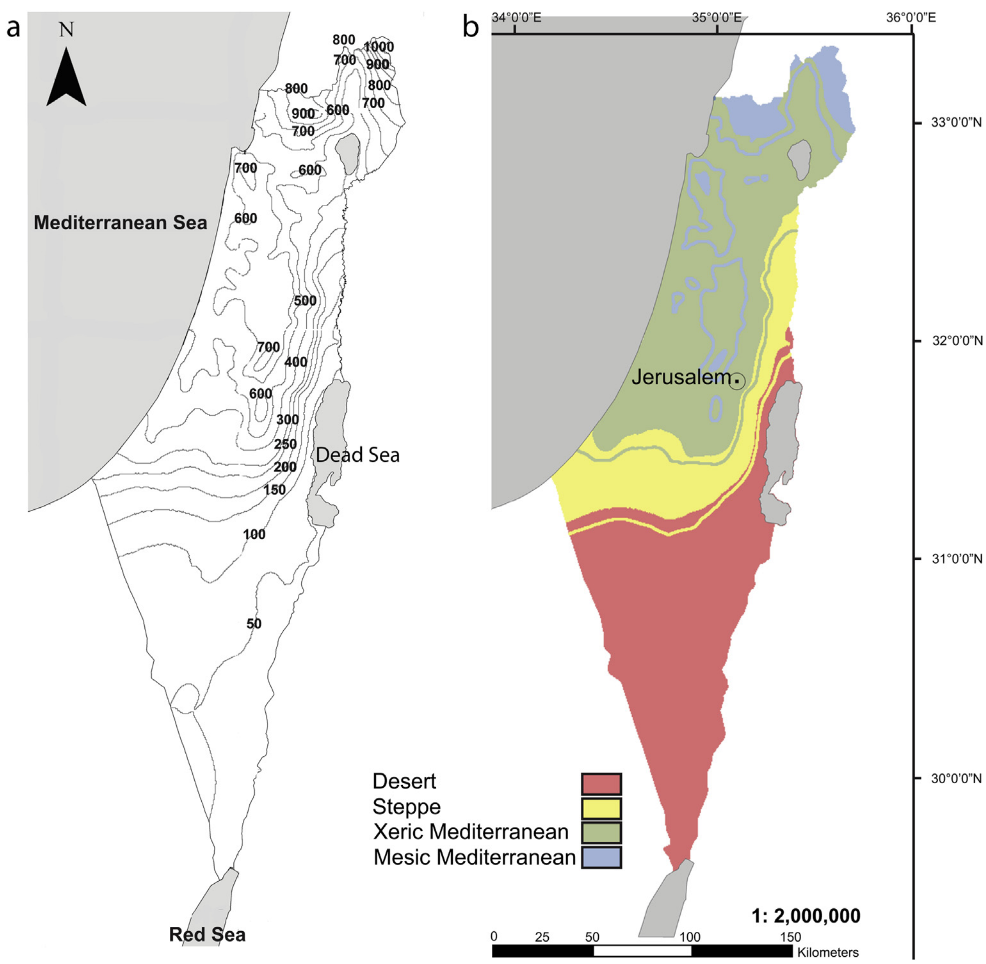

Fig. 2. Environmental maps of the southern Levant. **a**. Modern isohyet map of the region (mm/yr) adapted from rainfall data from the Israel Meteorological Service between 1960 and 1991. **b**. Distribution of primary environments estimated using mean annual precipitation (see SI text 3 for details). The lines represent the hypothetical shift in the geographic distribution of the environmental belts based on a 15% increase in mean annual precipitation during the Early Roman Period.

2. Materials and methods

2.1. Determining the isotopic ranges of archaeological caprids and modern bovids from different local environments

The expected isotopic ranges for four environments (mesic Mediterranean, xeric Mediterranean, steppic and desert) are estimated using the isotopic values of archaeological caprids and modern day bovids of known geographic and environmental origin. Archaeological caprids include domesticated goats (*Capra hircus*) and sheep (*Ovis aries*) recovered from three early Roman period sites representing three different environments: mesic Mediterranean (Gush Halav), xeric Mediterranean (Burnat), and desert (Qumran). Modern bovids include mountain gazelles, dorcas gazelle, and ibex. The $\delta^{13}C$ and $\delta^{15}N$ values measured in the caprids and bovids are continuous variables, but are used here to assign specimens into the distinct environmental categories. Discriminant Function analysis (Minitab 16) was used to test how accurately bovids from known environmental origins can be assigned to the four environments based on isotopic data. While stable isotope values are measured on archaeological bone collagen, those from modern bovids are measured on horn keratin. Both tissues are proteinaceous, but differ primarily in their amino acid composition, and in their rate of formation and turnover. Studies measured the difference between the two tissues, and agree that there is a +1.9‰ difference between paired keratin and collagen $\delta^{13}C$ values from the same animal, and that correction for $\delta^{15}N$ values is unnecessary (O'Connell et al., 2001; Sponheimer et al., 2003; Hartman, 2011). The modern keratin $\delta^{13}C$ values are thus corrected by adding 1.9‰ so that they can be directly compared to bone collagen values.

2.2. Correcting and calibrating modern bovid data for Early Roman caprids

Recent anthropogenic combustion of fossil fuels since the beginning of the industrial revolution has altered the $\delta^{13}C$ values of atmospheric CO_2 (δC_{CO_2}) from −6.5‰ to ~ −8.2‰ (−1.7‰) (Leuenberger et al., 1992; Keeling et al., 2005; Valentino et al., 2008). The shift in δC_{CO_2} is fully expressed in the $\delta^{13}C$ values of modern and fossil C_3 and C_4 plants that fix atmospheric CO_2 in the production of plant matter (Marino and McElroy, 1991; Francey et al., 1999). The recent shift in δC_{CO_2} values is transferred to consumers who feed on plants, and therefore a correction must be made before modern and archaeological data can be compared. This correction according to the year in which the modern bovid was collected, and a full −1.7‰ is assigned to Early Roman caprids following Long et al. (Long et al., 2005) (See Supplementary Data Table 3).

Several paleoclimatic proxies including a high resolution cave speleothem carbonate isotope series (Bar-Matthews et al., 1997, 1998; Orland et al., 2009), stable isotopes from archaeological wood (Yakir et al., 1994), pollen from Dead Sea sediments (Neumann et al., 2007) and changes in the elevation of the Dead Sea shores (Enzel et al., 2003; Bookman et al., 2004), all agree that the Early Roman Period was wetter than the present. According to Bar-Matthews et al. (1997), the amount of rainfall recorded at Soreq Cave during wet periods over the past 7000 years was up to 15% higher than present day amounts and even higher during the Early Roman Period (Orland et al., 2009). To investigate the effect of increased rainfall on the predicted geographic boundaries of the four environments, the isohyet maps were adjusted by increasing the amount of rainfall by 15% (Fig. 2). This adjustment results in a negligible spatial shift in the environmental belts from the Mediterranean and steppic zones (a distance of 2 km in the east-west rainfall gradient near Jerusalem, and a distance of less than 10 km in the north-south gradient; Fig. 2). The adjustment however, does increase the potential area of mesic Mediterranean environments west of Jerusalem. This reconstruction agrees with paleoclimatic reconstructions of shifting vegetation belts during the Holocene Epoch in the northern Negev (north-south rainfall gradient) (Goodfriend, 1990).

2.3. Sample processing and isotopic analysis

Bone shaft fragments weighing approximately 1 g were demineralized using 0.5 M EDTA following the method described in Tuross et al. (1988). The bone collagen was later washed in deionized water and agitated to remove the EDTA and then lyophilized. Keratin samples from the proximal end of modern gazelle and ibex horns were shaved with disposable scalpels (for complete list of samples see Supplementary data Supplementary Data Table 2). Keratin was used instead of bone because of the non-destructive nature of the sampling procedure to rare specimens (Hartman, 2011, 2012). The sampling area was first cleaned with an ethyl-alcohol swab. Since keratin is a pure protein material, surface cleaning is sufficient to remove adhering contaminants from the sampled keratin (confirmed by the atomic C/N ratio of the keratin samples [$n = 94$]: 3.59 ± 0.19, %N = 14.81 ± 1.49, %C = 44.62 ± 3.97). One milligram of bone collagen and horn keratin was weighed into tin boats and sent for isotopic analysis in the stable isotope laboratory at Boston University.

Archaeological bone collagen and modern keratin samples were analyzed using an automated continuous-flow isotope ratio mass spectrometer (Preston and Owens, 1983). The samples were combusted in a Euro-Vector Euro elemental analyzer. The combustion gases (N_2 and CO_2) were separated on a GC column, passed through a GVI diluter (GV Instruments) and reference gas box, and introduced into the GVI IsoPrime isotope ratio mass spectrometer. Water was removed using a magnesium perchlorate water trap. Ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ were expressed as the relative per mil (‰) difference between the samples and international standards [Vienna Pee Dee belemnite (V-PDB) carbonate and N_2 in air] where:

$$\delta X = \left(R_{\text{sample}}/R_{\text{standard}} - 1 \times 1000\left(‰\right)\right)$$

where $X = {}^{13}C$ or ^{15}N and $R = {}^{13}C/^{12}C$ or $^{15}N/^{14}N$

The sample isotope ratio is compared to a secondary gas standard with an isotope ratio that was calibrated to international standards. For ^{13}C V-PDB the gas was calibrated against NBS 20 (Solnhofen limestone, −1.05 ± 0.02%). For $^{15}N_{air}$ the gas was calibrated against atmospheric N_2 and IAEA standards N-1, N-2 [$(NH_4)_2SO_4$, 0.4 ± 0.2% and 20.3 ± 0.2% respectively], and NO_3^- (KNO_3, 4.7 ± 0.2%). All international standards were obtained from the National Bureau of Standards in Gaithersburg, Maryland. Internal standards were measured repeatedly during the analysis and provided the following results: pepton ($n = 26$, $\delta^{13}C = -14.83 \pm 0.06‰$, $\delta^{15}N = 7.23 \pm 0.23‰$); glycine ($n = 27$, $\delta^{13}C = -33.97 \pm 0.05‰$, $\delta^{15}N = 10.61 \pm 0.28‰$). The standard deviations for archaeological bone collagen duplicates ($n = 14$) are $\delta^{13}C = \pm 0.34‰$ and $\delta^{15}N = \pm 0.34‰$.

The %C and %N values were calibrated against known quantities of the internal peptone and glycine standards. A general bone collagen preservation criterion was applied to all of the archaeological samples following DeNiro (1985). If the C/N ratios (atomic ratio) of bone collagen samples did not fall within the range of 2.9–3.6, they were excluded from the analysis (Supplementary Data Table 3).

3. Results

3.1. Environmental assignment of archaeological caprids and modern bovids

Bone collagen preservation varied between archaeological sites: while Gush Halav, and Burnat yielded good quality collagen, Qumran yielded severely degraded collagen that had to be excluded from the analysis (Supplementary Data Table 3). Discriminant function analysis (DFA, Minitab 16) was used to classify the archaeological and modern herbivores from known origins into environmental groups. The original classification included four environmental groups: mesic Mediterranean, xeric Mediterranean, steppe, and desert. Overlap in the xeric Mediterranean and steppe $\delta^{13}C$ and $\delta^{15}N$ values ranges required that these two environmental groups be collapsed into a single steppic/xeric Mediterranean group (Fig. 3). Overall, 65.1% of the cases were correctly classified (Table 1, for complete classification data see Supplementary Data Table 1).

The desert environment group is well separated from other environments given that only 13% of the steppe/xeric Mediterranean and none of the mesic Mediterranean are misclassified as desert herbivores (Table 1). A much higher percentage of desert herbivores (39%) are misclassified as originating from wetter environments. This suggests that the DFA equations, have underestimated the size of the desert herbivore group by about 25%. The mesic Mediterranean herbivores were correctly classified in 84% of the cases (Table 1). The misclassification of animals to mesic Mediterranean environments likely overestimates the classification of the archaeological animals to this environment by about 25%. Steppe/Xeric Mediterranean herbivores were misclassified in 43% of the cases. The percent of misclassifications of animals from other environmental groups as steppe/xeric Mediterranean are identical (43%), suggesting that the percentage of archaeological caprids assigned to steppe/xeric Mediterranean environments may be correct.

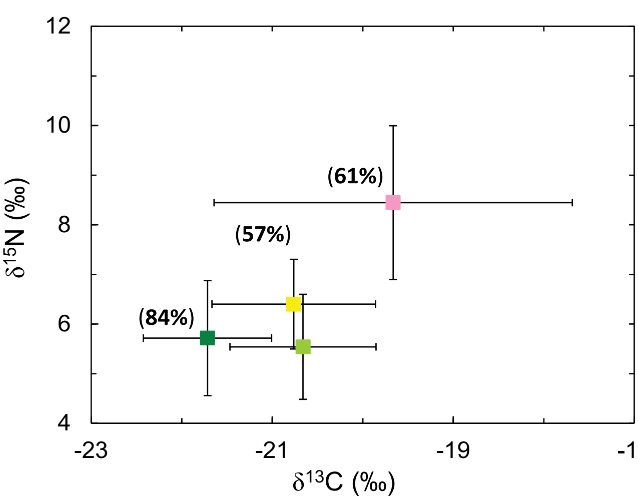

Fig. 3. Bivariable carbon and nitrogen isotope mean value plot of modern gazelles and ibexes. The values that include error bars (±1sd) are divided by environments: mesic Mediterranean (dark green); xeric Mediterranean (light green); steppe (yellow); desert (pink). Numbers in parentheses represent the percentage of bovids in each group that were correctly assigned to their environment.

3.2. Determining the environmental origins of archaeological caprid remains

Tell el Ful, one of the farm sites located in Jerusalem's northern hinterland is contemporaneous with Jerusalem's markets, while Shu'afat, postdates the temple destruction. Both Tell el Ful and Shu'afat have similar percentages of steppe/xeric Mediterranean animals (50% and 43% respectively). The two sites differ in the percentage of mesic Mediterranean and desert bovids. Tell el Ful has larger proportion of mesic Mediterranean animals (35%) compared with Shu'afat (17%), and a lower proportion of desert animals (15% and 40% respectively (Table 2; Fig. 4c)). The presence of mesic Mediterranean caprids in both farm sites is significantly higher than that measured in Jerusalem's city dump (see Section 3.3; *t*-test $p = 0.016$).

3.3. The environmental origin of caprids from Jerusalem's city dump

Samples were obtained from four locations in the refuse deposits of Early Roman Jerusalem (A1, A2, A3, A4). Of the 156 caprid samples from which well-preserved collagen was extracted, 53% originate from steppic/xeric Mediterranean environments, 37% from desert environments, and 10% from mesic Mediterranean environments (Fig. 4a, Table 2). Comparison of the isotopic values from different locations in the dump indicates a similar isotopic and environmental distribution (Single Factor Anova on percentages: $p < 0.0001$, Supplementary Data Fig. 1).

4. Discussion

Both carbon and nitrogen isotope values measured in modern wild bovids in the southern Levant have been shown to track the isotopic values of the vegetation on which they forage, be it natural (Hartman, 2011) or cultivated (Hartman, 2012). Because the carbon and nitrogen isotope values of plants vary according to water availability, it is possible to pinpoint the environment from which the herbivores originated. In this study, archaeological caprids from mesic and xeric Mediterranean sites, and wild bovids from steppe and desert environments could be segregated into three environmental groups: mesic Mediterranean, steppe/xeric Mediterranean, and deserts with 65% success overall (Table 1, Fig. 3). Misclassifications are directional in the cases of desert and mesic Mediterranean environments. Desert herbivores might be underestimated by up to 25%, because of erroneous assignment of modern desert bovids mostly to steppe/xeric Mediterranean but also to mesic Mediterranean environments. To the contrary, mesic-Mediterranean classification is likely to be overestimated by up to 25%. This is primarily caused by misclassification of steppe/xeric Mediterranean, and secondarily of desert herbivores, as mesic Mediterranean.

4.1. The environmental origins of Jerusalem's caprids

The environmental distribution of caprids from different locations in the Jerusalem dump is remarkably similar (see Results and Supplementary Data Fig. 1). This strongly supports the observation that the deposits were accumulated in one cultural and economical episode (Reich and Shukron, 2003). The environmental distribution further indicates a uniform pattern of caprid supply and marketing in the city throughout the Early Roman period. In all cases, up to 11% of the caprids originated in mesic Mediterranean environments. As discussed previously, this number is likely overestimated suggesting that the contribution of mesic Mediterranean caprids to Jerusalem is negligible. Because mesic Mediterranean regions are good habitats for intensive agriculture, which offers higher

Table 1
Environmental origins of modern bovids, discriminant function analysis (DFA).

Environment	Desert (0/41[a])	Steppe + xeric Mediterranean (13/10)	Mesic Mediterranean (19/0)
Mean $\delta^{15}N \pm sd$ (‰)	8.45 ± 2.57	5.91 ± 1.06	5.72 ± 1.16
Mean $\delta^{13}C \pm sd$ (‰)[b]	−19.66 ± 1.55	−20.70 ± 1.27	−21.72 ± 0.71
DFA (D)	$6.52 \times \delta^{15}N - 15.35 \times \delta^{13}C - 178.43$	$5.94 \times \delta^{15}N - 15.57 \times \delta^{13}C - 178.72$	$6.08 \times \delta^{15}N - 16.23 \times \delta^{13}C - 193.61$
Summary of classification[c]			
Desert	**25 (61%)**	3 (13%)	0 (0%)
Steppe + xeric Mediterranean	12 (29%)	**13 (57%)**	3 (16%)
Mesic Mediterranean	4 (10%)	7 (30%)	**16 (84%)**

Total correct assignments (54/83) 65.1%.
Environmental assignment of archaeological samples from unknown origins was made using the Linear Discriminant Functions (D) generated for each one of the environments. Algorithm (Microsoft excel) was used to assign the environment to the highest D value for each archaeological sample.
[a] Number of archaeological caprids/modern bovids in each environmental group.
[b] Modern horn keratin $\delta^{13}C$ values of bovids are corrected for bone collagen values (+1.9‰) and all values are corrected for post industrial revolution changes to atmospheric δC_{CO_2} values (+1.7‰) (for justifications see methods in main text).
[c] Number of correctly assigned herbivores in bold, and erroneously assigned in regular font, their percentages of total number of samples in the group are in parentheses.

economic returns than commercial herding, it is likely that caprids in these habitats were raised on the household level. Mesic Mediterranean caprids found in the Jerusalem dump were thus likely transported to Jerusalem by local pilgrims from mesic Mediterranean regions such as the western Judean Hills and the Upper Galilee for sacrifice in Jerusalem as specified in the Old Testament and Talmudic sources. The small percentage of mesic Mediterranean caprids in the archaeological assemblages provides little evidence for direct contribution of pilgrims to the meat industry in Jerusalem. The possibility that xeric Mediterranean caprids were also brought to the city by pilgrims is not excluded, but in this case is it impossible to discern commercial caprid trade from direct transportation by pilgrims.

Caprids from steppe/xeric Mediterranean comprised 52% of the animals analyzed in this study (Table 2). This in part can be attributed to commercial caprid breeding and herding in farms surrounding Jerusalem, especially east of the city where a drop in rainfall caused by the rain shadow effect made sustainable agriculture uneconomical (Baruch, 1999). The farm sites of Shu'fat and Tell el Ful that are located about 5 km north of Early Roman Jerusalem on the watershed line and thus provide important information on local production of animals for the city. The caprids of Shu'fat and Tell el Ful show a similar proportion of steppe/xeric Mediterranean caprids (~47%, Table 2), and much higher percentages of mesic Mediterranean caprids (25%). This finding weakens the hypothesis that these farms, and perhaps other farms that surrounded Jerusalem, provided a major source of caprids to the city.

The most striking result of this study is that no less than 37% and up to over half of the caprids deposited in Jerusalem's dump originated from desert environments (Table 2, Fig. 4a). More importantly, these desert animals likely had to travel a substantial distance before they arrived in Jerusalem. The closest desert to Jerusalem is the Judean Desert located directly east of the city. The drier parts of the Judean Desert (<150 mm/yr) are located at least 20 km east of the city (elevation difference of >1000 m) which is beyond the daily reach of herders living in Jerusalem's immediate surroundings (Turner and Hiernaux, 2002). Because of the low plant biomass productivity and associated low carrying capacity of desert environments (Archibold, 1995), caprid herd density is severely limited in deserts. Thus, the small area of the Judean desert that is included within the boundaries of the province of Judea (<1000 km^2) could have only provided a small fraction of the desert animals that were marketed in Jerusalem. It follows that most of the desert caprids that were identified in Jerusalem refuse deposits must have arrived from outside of the province's boundaries. This observation provides strong evidence for large-scale organized inter-provincial trade of desert bovids to Jerusalem markets throughout the Early Roman period. Talmudic sources post-dating the destruction of the temple by over two centuries indicate that Edomite merchants imported thousands of caprids from desert regions (Applebaum, 1976b; Safrai, 1994). This is the first archaeological support of the textual evidence describing Jerusalem's pilgrimage economy. The data from the xeric Mediterranean site of Burnat, on the western slopes of the Judean Hills provides unique evidence for further movement of desert animals from Jerusalem's markets into strictly Mediterranean environments. Three of the caprids from Burnat plot unequivocally in desert environments (Fig. 4b, Supplementary Data Table 3). The distance between Burnat to the nearest desert region (>60 km) makes it highly unlikely that herds traveled such a distance given high population density during the Early Roman period. This evidence suggests that the large influx of desert caprids into Jerusalem served not just for a sacrificial purpose, but also provisioned regional traders or even local pilgrims for domestic use when the transport of these animals was feasible. This is not surprising given that Biblical sources state that animals were disqualified for sacrifice if found to be in below perfect conditions (Leviticus 22:27; Deuteronomy, 17:1). Under such conditions, many caprids with minor physical imperfections could have been marketed for secular needs.

In summary, the contribution of Jewish pilgrims was clearly a major *stimuli* for Jerusalem's economy, both through local production in surrounding farms and through inter-provincial trade in the Early Roman period. Importantly, the strong presence of foreign desert caprids in Jerusalem's refuse deposits provides the first hard evidence of the importance of the pilgrim economy that fueled the local economy during the Early Roman period.

Table 2
Reconstructing the environmental origins of Jerusalem's caprids.

Location	Mesic Mediterranean *n* (%)	Steppe/xeric Mediterranean *n* (%)	Desert *n* (%)	Total caprids
Shua'fat	5 (17%)	13 (43%)	12 (40%)	30
Tell el Ful	9 (35%)	13 (50%)	4 (15%)	26
Jerusalem A1	4 (9%)	27 (63%)	12 (28%)	43
Jerusalem A2a	2 (11%)	10 (53%)	7 (37%)	19
Jerusalem A2b	2 (11%)	7 (39%)	9 (50%)	18
Jerusalem A3	5 (14%)	20 (57%)	10 (29%)	35
Jerusalem A4	3 (7%)	19 (46%)	19 (46%)	41
Jerusalem Totals *n* (% ± sd)	16 (11 ± 3%)	83 (53 ± 9%)	57 (36 ± 10%)	156

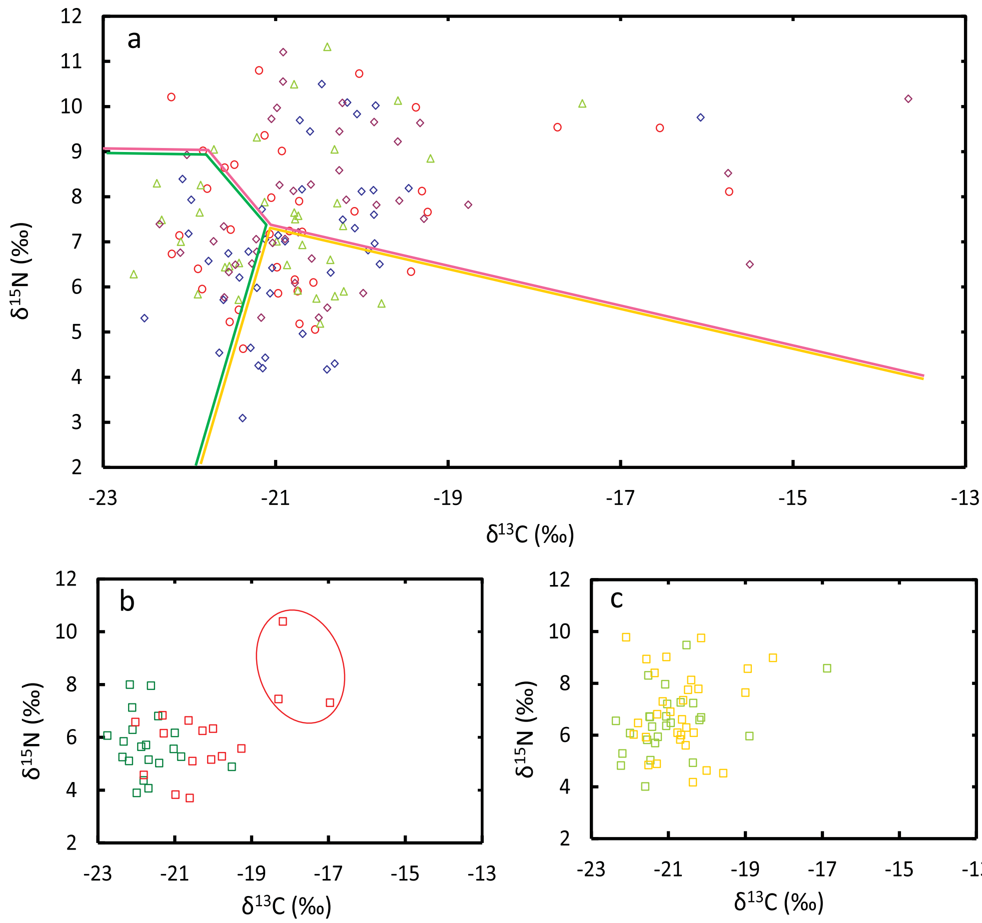

Fig. 4. Bivariable carbon and nitrogen isotope values plot of Early Roman caprids. **a**. Jerusalem garbage, divided into environmental squares (mesic Mediterranean; steppe/xeric Mediterranean; desert), and into different sampling locations: A1: blue diamonds; A2: red diamonds; A3 green triangles; A4 purple diamonds. **b**. Mesic (Gush Halav, green squares) and xeric Mediterranean (Burnat, red squares) caprids. Desert caprids from Burnat are circled. **c**. Farm sites from the vicinity of Jerusalem: Shu'fat (yellow squares) and Tell el Ful (green squares).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2013.07.001.

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