Complex caprine harvesting practices and diversified hunting strategies: Integrated animal exploitation systems at Late Pre-Pottery Neolithic B 'Ain Jamman

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ABSTRACTS

Sheep and goat herding formed the central component of the animal-based portion of Late Pre-Pottery Neolithic subsistence economies in the southern Levant, but a detailed understanding of the diversity of animal exploitation systems and the array of caprine management practices employed during the Late PPNB, a dynamic cultural period distinguished by dramatic shifts in settlement systems and social organization, is remarkably lacking. New species abundance, metrical, and demographic data from 'Ain Jammam, a large Late PPNB settlement located in southern Jordan, indicate a complex animal exploitation system was in use at the site and entailed intensive management of domestic caprines, sustained exploitation of wild ungulates, and use of new animal technologies. The variety of complementary caprine harvesting strategies employed at 'Ain Jammam, including moderate kill-off of young male sheep and delayed, but extensive, harvesting of male goats while promoting female survivorship, suggest scheduled use and extraction of ante- and post-mortem animal resources. The relatively high abundance of gazelle in the 'Ain Jammam assemblage indicates that the animal served as an important, perhaps seasonal, meat resource that supplemented foodstuffs obtained from domesticated caprines. High variation in cattle body size and represented demographic groups, as well as over-representation of low-utility body parts, suggests exploitation of both wild and managed taurines at the site. These zooarchaeological data from 'Ain Jammam suggest that Late PPNB herding and hunting activities comprised a completely new animal subsistence package that integrated new developments in caprine and taurine management strategies with pre-existing animal husbandry and hunting systems in order to meet increased demand for animal resources spurred by shifts in human settlement patterns toward dense inhabitation of aggregate settlements.

KEY WORDS
Near East,
caprine husbandry,
cattle exploitation,
harvesting.

RÉSUMÉ

Pratiques complexes d'exploitation des Caprinés et stratégies de chasse multiples : systèmes d'exploitation intégrés des animaux au PPNB récent à 'Ain Jammam

L'élevage des moutons et des chèvres fut un élément essentiel de la composante animale de l'économie de subsistance au PPNB récent dans le Levant méridional, mais une compréhension précise de la diversité des systèmes d'exploitation des animaux et de la diffusion des pratiques liées à l'exploitation des caprinés pendant le PPNB récent – une période culturelle dynamique qui se distingue par des variations spectaculaires des fondements de l'organisation des systèmes et des sociétés — manque cruellement. L'abondance des données nouvelles métriques et démographiques recueillies à 'Ain Jammam — un vaste site du PPNB récent situé en Jordanie méridionale — indique qu'un système d'exploitation animale complexe était établi sur ce site et qu'il a nécessité la gestion intensive des Caprinés domestiques, l'exploitation soutenue des Ongulés sauvages et la pratique d'une nouvelle technologie liée à l'animal. La variété des stratégies complémentaires d'élevage des Caprinés à 'Ain Jammam, incluant l'abattage contrôlé des jeunes moutons et le contrôle tardif, mais intensif, des boucs en faveur de la sélection des femelles, suggèrent la gestion programmée et l'exploitation des ressources animales, mortes ou vivantes. L'abondance relativement élevée de la gazelle dans l'assemblage d'Ain Jammam indique que cet animal était une importante, et sans doute saisonnière, ressource de viande qui a complété les produits alimentaires obtenus à partir des Caprinés domestiqués. La variation élevée de la dimension des individus du troupeau et des groupes démographiques représentés, comme la surreprésentation des parties du corps les moins utilisées, suggère l'exploitation conjointe des bovins sauvages et domestiqués sur le site. Les données archéozoologiques de 'Ain Jammam suggèrent, qu'au PPNB récent, l'élevage et la chasse ont conjointement constitué un nouveau système de subsistance intégrant le développement des stratégies de gestion de Caprinés et des Bovins, incluant eux-mêmes les systèmes préexistants d'élevage et de chasse, afin de satisfaire la demande accrue des ressources animales générée par le changement des types de peuplements humains, du dispersement à la densification.

INTRODUCTION

The emergence of mixed sheep and goat herding in the southern Levant approximately 8,000 years ago during the Late Pre-Pottery Neolithic B (7300-6900 cal BC) was an important development in local animal exploitation systems that expanded and intensified the intentional production of animal products. This development in animal-use systems coincided with the appearance throughout central and southern Jordan of multiple, densely built aggregate settlements and novel cultural practices suggestive of increased emphases on social differentiation and private property and signaled dramatic shifts in the character and organization of PPNB societies (Kuijt & Goring-Morris 2000, Wright 2000). Previous zooarchaeological research has clearly demonstrated the central role of caprine herding in Late PPNB subsistence economies, but the organization of and variation in Late PPNB animal subsistence systems remains poorly defined and is limited to a very broad characterization suggesting a heavy reliance on the pastoral production of caprine meat, opportunistic exploitation of gazelle, and possible use of managed cattle (Becker 1991, von den Dreisch & Wodtke 1997, von den Driesch *et al.* 2004). Species- and sex-specific harvesting strategies, particularly those applied separately to

sheep and goats and male and female caprines, and evidence for exploitation of animals other than for their meat, are unknown.

Here, the range and variation of herding and hunting practices employed at a Late PPNB settlement are examined through high-resolution analysis of species abundance, biometric, and demographic data recovered from 'Ain Jammam, a Late PPNB settlement located in the southern Jordan. The 'Ain Jammam assemblage provides a new source of faunal data concerning the nature of Late PPNB animal use and is used to examine if Late PPNB herders employed an animal exploitation system that included multiple caprine harvesting strategies differentially applied to sheep and goats and male and female animals, and used a hunting system focused on the targeted exploitation of multiple ungulate groups according to the seasonal and ecotonal availability of wild animal resources.

THE SITE OF 'AIN JAMMAM:
SITE CHRONOLOGY MATERIAL
CULTURE, AND ENVIRONMENT

'Ain Jammam is a large Late PPNB settlement approximately 7 hectares in size situated on an escarpment overlooking the Wadi Hisma near Ras an-Naqab (Fig. 1). The site was first identified as a Pre-Pottery Neolithic settlement during an intensive survey of the wadi system and was seriously threatened in the mid-1990's by new construction work on the Desert Highway (Gebel 1992). Emergency excavations conducted by the Cultural Resource Management unit of the Jordanian Department of Antiquities were undertaken in 1995 and 1996 in an effort to record threatened PPNB cultural deposits.

'Ain Jammam is categorized chronologically as a Late PPNB settlement on the basis of lithic techno-types, architectural construction styles, and radiocarbon determinations recovered from deposits. Byblos and Amuq points, tools commonly encountered in Late PPNB deposits across the southern Levant, are the dominant formal tool classes represented at 'Ain Jammam (Rollefson 2005). Other Late PPNB-type tools, including unifacially retouched knives, borers, and drills produced on bladelets, have also
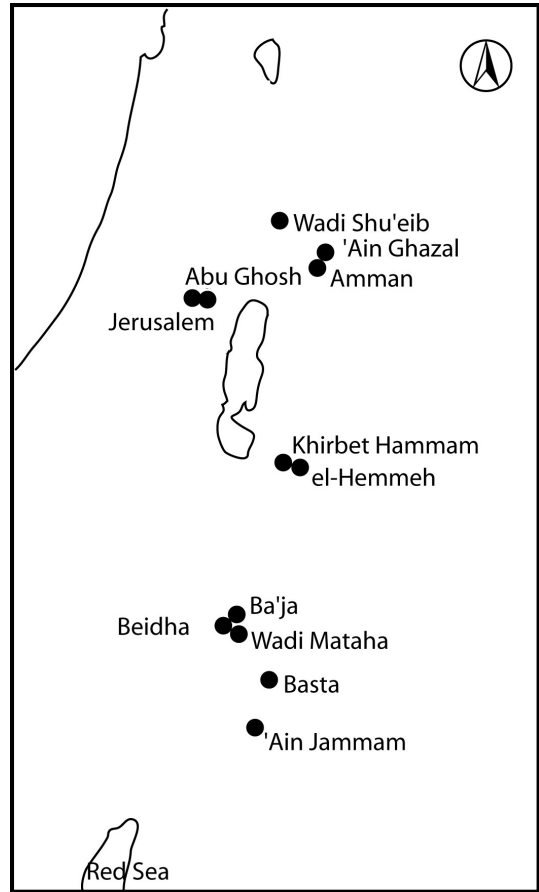

Fig. 1. — Map showing the location of 'Ain Jammam and other sites discussed in the text.

been recovered from the site (Rollefson 2005). 'Ain Jammam also exhibits multiple architectural similarities with several other Late PPNB settlements located in central and southern Jordan, including dressed limestone slab wall constructions ~2m in height and quadrilateral, cell-like spaces ranging in size from ~1.4 m^2 to 17 m^2 that together form agglutinative structural complexes (Gebel 2006, Gebel & Bienert 1997, Makarewicz *et al.* 2006). Only two radiocarbon determinations are available for 'Ain Jammam, and, the exact provenances of the dated charcoal samples are poorly documented (Waheeb & Fino 1997). Each sample was selected from cultural deposits exposed by an illegal bulldozer cut running through the site and it is unk-

nown if the samples were selected from primary or secondary depositional contexts. The first sample, retrieved from the "lowest" portion of the stratigraphic sequence exposed by the cut, yielded a date of 8520 ± 190 bp (7810-7298 cal BC; +/- 1σ). The second sample, retrieved from somewhere "near the center of the sequence" dates to 8030 ± 120bp (7087-6720 cal BC; +/- 1σ) (Fino 2004). Each determination is chronologically consistent with dates obtained from other Late PPNB sites in the region, but additional dates from secure contexts are needed in order to better establish the duration of settlement occupation at 'Ain Jammam.

The majority of cultural deposits uncovered at 'Ain Jammam appear to be Late PPNB in origin, but it is likely that the site contains a Pottery Neolithic component as well. An oval-shaped building containing Yarmoukian banded herringbone incisioned pottery is described in a yearly review of archaeological work conducted in Jordan (Bikai & Egan 1996), but neither the structure nor the pottery are discussed in either of the two brief publications produced for the site (Waheeb & Fino 1997; Fino 2004). Lithic analyses suggest that several of the contexts previously attributed to the Late PPNB during excavations are actually Pottery Neolithic in origin (Rollefson 2006, personal communication); faunal remains recovered from these contexts were not included in the analysis presented here. In addition, Fino *et al.* (2004) states, on the basis of perceived stylistic differences in wall constructions around the site, that 'Ain Jammam was also occupied during the PPNC. The absence of PPNC radiometric determinations and lithic techno-types identified at 'Ain Jammam suggest, however, additional Late PPNB re-modifications of an original, initial phase Late PPNB structure rather than later PPNC alterations.

Today, 'Ain Jammam is situated with a transitional phytogeographic zone containing elements of both Mediterranean and Irano-Turanian vegetational elements. Rainfall levels average 300mm per year, with the majority of precipitation falling during the winter and spring months. Unfortunately, there is little paleoenvironmental information available specific to the immediate area surrounding 'Ain Jammam. Carbonized seed remains from emmer wheat (*Triticum dicoccum*), barley (*Hordeum distichum* and *H. vulgare*), chickpea (*Cicer arietium*), figs (*Ficus* sp.), and grapes (*Vitis* sp.) recovered from deposits suggest a similar or slightly wetter environment during the Late PPNB relative to today.

ZOOARCHAEOLOGICAL METHODS

The comparative collection located in the Zooarchaeology Laboratory, Peabody Museum, Harvard University, as well as morphological criteria established by Boessneck *et al.* (1964), Payne (1985), and Uerpmann and Uerpmann (1986), was used to aid in identifications of 'Ain Jammam bone specimens. Age data used to calculate survivorship curves were determined according to the state of epiphyseal fusion of appendicular skeletal elements and the eruption and wear stages of mandibular teeth. These two data sources are not directly comparable to each other, but together, provide age information spanning the entire life of an animal. Although Silver's (1969) estimation of animal age at fusion of epiphyses is typically used for the purposes of constructing kill-off profiles, here, Zeder's (2006a) fusion schedule is used. Zeder's estimates of fusion age are based on a large sample of epiphyseal fusion data collected from modern Near Eastern wild caprines, including *Capra aegagrus*, *Ovis orientalis*, and *O. vignei*, and likely serve as a more appropriate standard for evaluating the timing of epiphyseal fusion in prehistoric caprines (Zeder 2006a). The epiphyseal fusion sequence established by Davis (1980) is used here to calculate survivorship curves for gazelle. Caprine tooth wear stages were recorded according to Payne (1973) and cattle tooth wear stages according to Grant (1982).

Metrical data are useful for distinguishing between the bones of wild and domestic animals, tracking shifts in animal exploitation strategies that are linked with changes in animal size, and identifying sex-specific animal management practices. Individual measurements of both fused and unfused skeletal elements were taken according to von den Driesch (1976) and Davis (1996). LSI values, calculated according to Meadow (1999), were compared against LSI values computed for the averaged measurements of a modern male and modern female *Capra aegagrus* from the Taurus mountains, and

a female *Ovis orientalis* from Iran (Uerpmann & Uerpmann 1994).

Sex-specific demographic curves for goat and sheep were calculated according to a protocol modified from Zeder (2001). Since the fused bones of adult female caprines are smaller than the fused bones of adult males, and the unfused bones of juvenile males are larger than the fused bones of females in all but the youngest male animals (Zeder 2001, 2006b), it is possible to estimate the proportion of specimens likely belonging to male and female goats, and to a lesser extent sheep, within a particular category of skeletal element (Hesse 1984, Zeder & Hesse 2000, Zeder 2001). A bimodal distribution of fused skeletal parts is interpreted to reflect sexual dimorphism, with smaller specimens likely representing primarily females and larger specimens consisting largely of males. In the absence of a clearly bimodal size distribution observable in 'Ain Jammam goat skeletal parts, metrical data from likely male and female animals from Ganj Dareh were used as a reference to help distinguish between the two groups.

Although Zeder's work demonstrates that unfused specimens lying within the distribution of fused, large-sized bones of males likely belong to male animals, the case for unfused specimens lying within the distribution of fused, smaller sized bones of females is not as clearly defined. The unfused bones of female animals do overlap exclusively in size with the fused bones of adult females, but the bones of male animals from Zeder's age class A, *i.e.* animals younger than one year, exhibit the same metrical distribution as unfused and fused bones of females as well. It is possible, therefore, that the smallest unfused bones visible in a size distribution belong to *either* male or female animals. In order to categorize specimens consistently, unfused bones overlapping with fused small-sized bones are categorized here as 'male', and unfused bones smaller than fused small-sized bones are categorized as 'female'. It is expected that juvenile females are under-represented using this categorization schedule.

In addition, this research does not calculate 90% confidence limits in order to eliminate potential areas of overlap between the size distributions of adult male and female populations, as called for in Zeder's original protocol (Zeder 2001). It is also emphasized that, here, the calculation of sex-specific curve entails the manipulation of a data pool that is already heavily reduced in size relative to the data pool used to calculate caprine and sheep- and goat-specific survivorship curves. Since the bones used to produce sex-specific kill-off profiles represent only a very small portion of the total assemblage of bones exhibiting epiphyseal fusion and metrical data, it is more appropriate to interpret general trends in sex-specific curves rather than analyze exact percent survivorship. In addition, the bones of the very youngest animals, which often lack well-defined morphological characters attributable to either sheep or goat, are likely to be highly under-represented in the sex-specific curve. For those specimens identified to sheep or goat, the absence of measurable morphological points due to high fragmentation of fragile young animal bone, further contributes to the under-representation of young animals in sex-specific survivorship curves.

FAUNAL SPECIMEN RECOVERY

Unfortunately, the method of bone specimen recovery employed during excavations at 'Ain Jammam is unknown. The low frequency of lithic debitage 2 cm or less in size identified in the stone tool assemblage strongly suggests that screening was not systematically employed during excavations (Rollefson 2005). Small mammals, bird, fishes, and juvenile and infant-aged animals tend to be under-represented in faunal assemblages recovered without the use of screening (Payne 1975).

In order to estimate the impact of recovery method on the 'Ain Jammam faunal assemblage, a recovery index was calculated according to the ratio of individual first phalanx and smaller second phalanx specimens (Maltby 1985, Russel & Martin 2005; Arbuckle 2006). This recovery index is based on the premise that the first and second phalanges are unlikely to be intentionally disarticulated or fractured during carcass processing so that a ratio of 1:1 should indicate equal recovery of the two differentially-sized skeletal elements . The recovery index for the 'Ain Jammam assemblage is 3.69 and indicates either poor recovery of second phalanges or high fragmentation of first phalanges. The 'Ain

TABLE 1. – Recovery indices based on the ratio of first and second phalanges for sieved and unsieved assemblages from a variety of cultural periods and geographic regions in the the Near East.
EP = Epipaleolithic; PPNA = Pre-Pottery Neolithic A; PPNB = Pre-Pottery Neolithic B; PN = Pottery Neolithic; CH = Chalcolithic; EB = Early Bronze Age; MB = Middle Bronze Age.

	Period	Ph1/Ph2	Recovery method	Reference
El Wad	EP	1.33	Wet-sieve	Bar-oz (2005)
Nahal Hadera V	EP	1.20	2mm dry sieve	Bar-oz (2005)
Hefzibah 1-7	EP	1.50	2mm dry sieve	Bar-oz (2005)
Hefzibah 7-18	EP	1.28	2mm dry sieve	Bar-oz (2005)
Neve David	EP	1.15	3mm dry sieve	Bar-oz (2005)
WF 16	PPNA	1.53	2mm dry sieve	personal observation
El-Hemmeh	PPNB	1.60	2mm dry sieve	personal observation
'Ain Jammam	**PPNB**	**3.69**	**Sporadic sieving?**	
Basta	PPNB	2.39	2mm and dry sieve	Becker (2004)
Ba'ja	PPNB	n/a	No sieving	von den Driesch *et al.* (2004)
Erbaba	PN	1.33	Sieving	Arbuckle (2006)
Kosk II-IV	PN	1.63	No sieving	Arbuckle (2006)
Kosk I	CH	2.13	No sieving	Arbuckle (2006)
Guvercinkayasi	CH	1.74	No sieving	Arbuckle (2006)
Khirbet Minsahlat	EB	1.08	5mm sieving	Makarewicz (2005)
Acemhoyuk II	MB	4.25	No sieving	Arbuckle (2006)
Acemhoyuk III	MB	4.11	No sieving	Arbuckle (2006)

Jammam recovery index is markedly higher than indices calculated for faunal assemblages retrieved through wet-sieving, a 2mm-sized screen, a 5mm-sized screen, or no screen (Table 1) and suggests that the 'Ain Jammam assemblage suffers from recovery bias, and, we should expect under-representation of skeletal parts belonging to small-sized and infant aged mammals and the unfused epiphyses of young medium-sized mammals.

'AIN JAMMAM FAUNAL DATA

A total of 1106 bone specimens identified to genus-level from the Late PPNB layers of 'Ain Jamman were analyzed (Table 2). The assemblage is comprised primarily of goat, sheep, gazelle, and cattle remains, a faunal composition that is similar to other Late PPNB sites in central and southern Jordan (Becker 1991; von den Driesch and Wodtke 1997, von den Driesch *et al.* 2004; Peterson 2004; Richardson

1997). A variety of other animals including equids, deer, pigs, foxes, canids, rock hyrax, felids, fish, tortoise, and birds were also identified in the 'Ain Jammam assemblage.

CAPRA SP.

Goats, whose bones comprise c. 39% of the Late PPNB faunal assemblage, were the primary taxon exploited at 'Ain Jammam (Table 2). Three goat taxa may be represented in the 'Ain Jammam assemblage, including domestic *Capra hircus*, wild *C. aegagrus*, and wild *C. ibex*. The prehistoric biogeographic distribution of *C. aegagrus* extended from the Taurus and Zagros mountains into the southern Levant, while *C. ibex* was largely restricted to the Negev and southern Jordan (Uerpmann 1987, Bar-Gal *et al.* 2002, Wasse 2002). In central and southern Jordan, bezoar horn cores have been recovered from Middle PPNB contexts at Beidha and 'Ain Ghazal, and ibex horn cores retrieved from Middle PPNB deposits at Beidha and Late PPNB deposits at Ba'ja

TABLE 2. — Number of identified specimens (NISP) and frequencies of identified taxonomic groups from the Late PPNB levels of 'Ain Jammam.

	NISP	Frequency (%)
Bos sp.	89	8
Equus sp.	14	1.3
Capra sp.	435	39.2
Ovis sp.	328	29.3
Gazella sp.	138	12.4
Dama sp.	1	<1
Capreolus sp.	7	<1
Sus sp.	5	<1
Lepus sp.	8	<1
Procavia sp.	1	<1
Vulpes sp.	23	2
Felis sp.	1	<1
Canis sp.	5	<1
Testudo sp.	1	<1
Osteichthyes	44	4.4
Aves	6	<1
Total	**1106**	**100**

and Basta (Hecker 1982, Wasse 2002, Becker 2004, von den Dreisch & Wodtke 2004). A single ibex horn core was recovered from 'Ain Jammam.
LSI values for 'Ain Jammam goats are compared with those from Middle Paleolithic Ksar 'Akil, Natufian Wadi Mataha, Middle PPNB Abu Ghosh, and Late PPNB Basta and Ba'ja (Fig. 2). On average, the 'Ain Jammam goats are considerably smaller than large-bodied, morphologically wild populations from Ksar 'Akil and Wadi Mataha, as well as morphologically wild, but likely managed, animals from Abu Ghosh. 'Ain Jammam goats exhibit similar LSI values to those from Basta and Ba'ja, although there is a greater number of specimens at the small end of the size range at 'Ain Jammam and Ba'ja compared to Basta.

OVIS SP.
Sheep are the second most abundant taxon (c. 29%) represented in the 'Ain Jammam assemblage and likely represent a domesticated population. The absence of sheep identified in southern Levantine Natufian, PPNA, or Middle PPNB assemblages
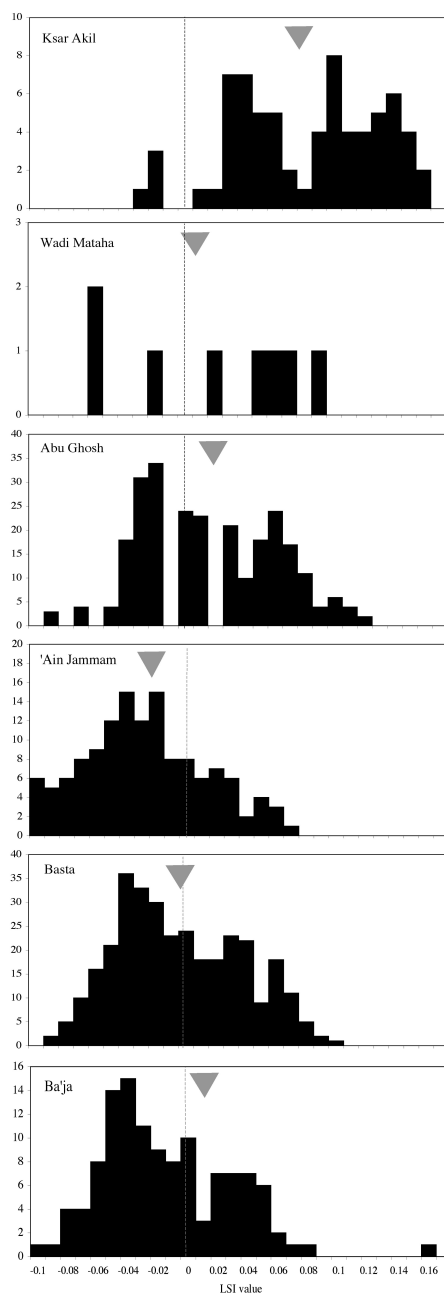

FIG. 2. — LSI values for goat skeletal parts from Ksar Akil (n = 70), Wadi Mataha (n = 8), Abu Ghosh (n = 307); Basta (n = 328); Ba'ja (n = 118) and 'Ain Jammam (n = 133) (Kersten 1987; Whitcher *et al.* 2000; Horwitz 2003; Becker 2004; von den Driesch *et al.* 2004). Triangles indicate mean LSI values. LSI values for Basta sheep were calculated using metrical data from specimens identified as wild *C. aegagrus/ibex* and domestic *C. hircus* (Becker 2004).
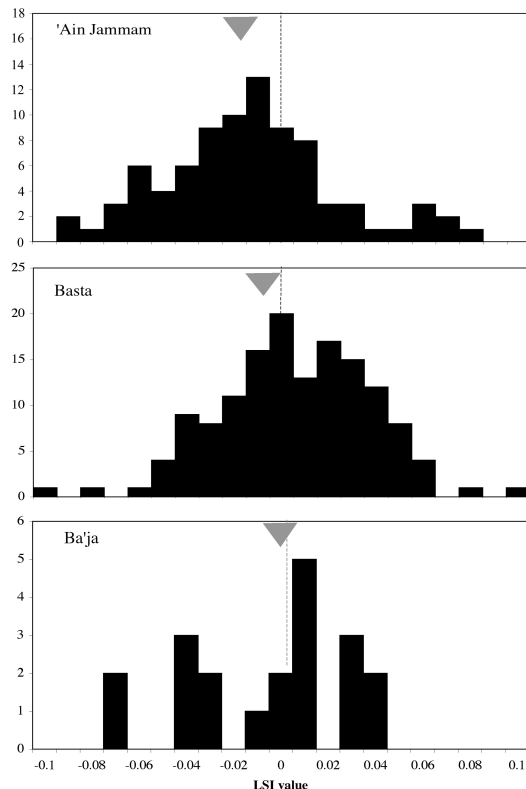
FIG. 3. — LSI values for sheep skeletal parts from Basta (n = 142) Ba'ja (n = 20) and 'Ain Jammam (n = 85). Triangles indicate mean LSI values. LSI values for Basta sheep were calculated using metrical data from specimens identified as wild *O. orientalis* and domestic *O. aries* (Becker 2004). Metrical data for Ba'ja is from von den Driesch *et al.* 2004.

suggests that the biogeographic distribution of *Ovis orientalis* did not extend into this region during the early Holocene (Horwitz & Ducos 1998). Sheep first appear in southern Levantine archaeological contexts during the Late PPNB, and, it is likely the animal was imported as a domesticate from the northern Levant (Horwitz *et al.* 1999, Bar-Yosef 2000, Wasse 2002). Although wild sheep have been reported at Basta (Becker 2004), the large-sized bones of ibex exhibit several sheep-like morphological characteristics (von den Driesch & Wodtke 2004, Kolska-Horwitz 2006, pers. com., Arbuckle 2005, pers. com.).

LSI values for sheep from 'Ain Jammam exhibit a similar mean and range as those from Basta and Ba'ja, although 'Ain Jammam values are heavily

weighted toward the small end of the total size range (Fig. 3). The inclusion of specimens identified as large-bodied *O. orientalis* in the Basta assemblage explains the relative left skew seen in 'Ain Jammam sheep LSI values.

GOAT AND SHEEP SURVIVORSHIP CURVES

Survivorship curves computed from the tooth eruption and wear data from loose mandibular teeth for 'Ain Jammam caprines are presented in Figure 4 (n = 54). The combined sheep/goat curve indicates caprine survivorship is high during the first year of life. There is significant kill-off of animals aged at Mandibular Wear Stage D, with only 48% of caprines surviving to 2 years in age. Kill-off slackens somewhat for animals aged between 2 and 3 years, and then intensifies again for older animals, with only 20% of animals surviving beyond four years.

Survivorship based on the degree of epiphyseal fusion of goat (n = 283), sheep (n = 202), and sheep/goat (n = 188) long bone specimens are presented in Figure 5. Survivorship for 'Ain Jammam goats is moderate throughout the first year and a half of life, with c. 88% of animals surviving beyond 18 months. The theoretical goat cohort is then further reduced, with only 58% of goats surviving past 30 months and 48% of animals surviving beyond 48 months. In contrast, survivorship levels for sheep are relatively high. Initially, survivorship for juvenile-aged 'Ain Jammam sheep are similar to those observed in goats, with c. 82% of sheep surviving beyond 18 months. Kill-off levels of sheep remains relatively low, with 74% of sheep surviving beyond 30 months and 53% past 48 months. The 'rebound' visible in age group F for all categories of caprines is due the small number of specimens available for this age category displaying state of epiphyseal fusion ($n_{O/C} = 4$, $n_{Capra} = 6$, $n_{Ovis} = 6$). Size distribution data for fused and unfused skeletal parts used to calculate sex-specific demographic curves for goats are presented, in relative order of fusion, in Figure 6. The distribution of measurements is bimodal for each fused skeletal part, indicating the presence of both small-sized females and large-sized males at varying life stages in the assemblage. Survivorship for male juvenile goats at
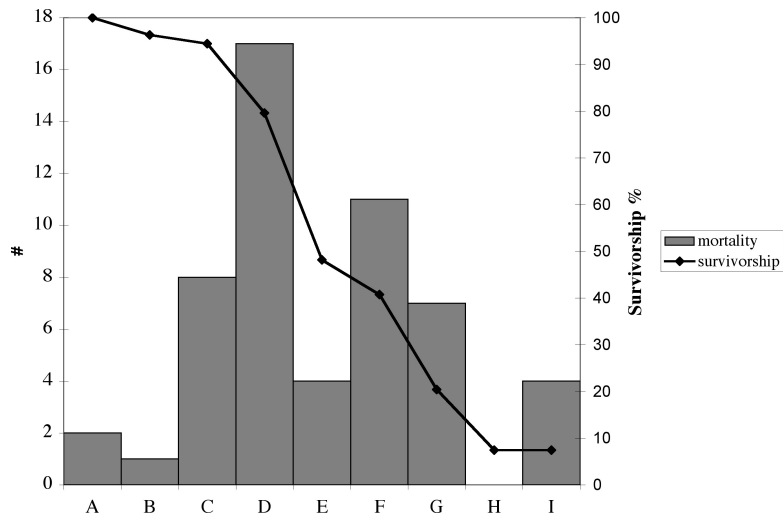
FIG. 4. — 'Ain Jammam survivorship (black line) and mortality (grey bars) for a combined sheep/goat category based on tooth wear stages according to Payne (1973; n = 54). Mandibular Wear Stage (MWS) **A** = 0 – 2 months, **B** = 2 –6 months, **C** = 6 –12 months, **D** = 1 –2 years, **E** = 2 –3 years, **F** = 3 – 4 years, **G** = 4 – 6 years, **H** = 8 –10 years.
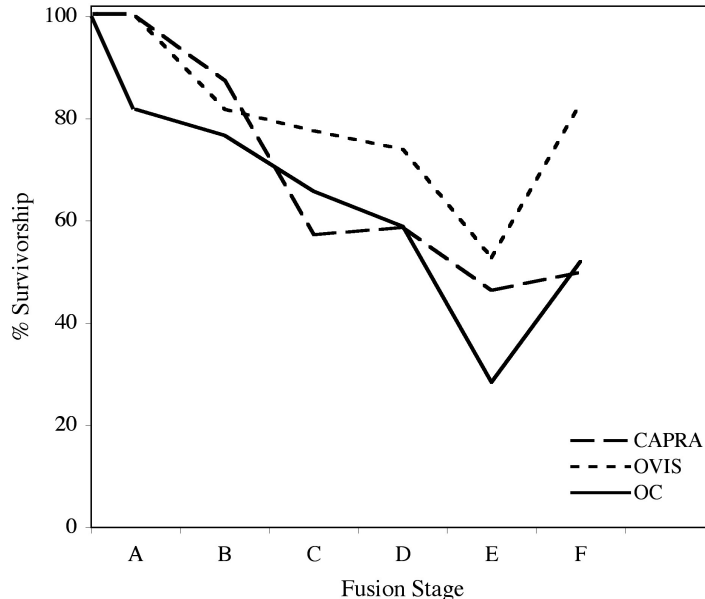

FIG. 5. — Survivorship curves computed from the state of epiphyseal fusion of long bone specimens identified as sheep, goat, and sheep/goat from 'Ain Jammam. Dashed line represents goats (*n* = 283), dotted line represents sheep (n = 202), solid line represents a combined sheep/goat category (n = 188). Age groups classified according to epiphyseal fusion stages defined by Zeder (2006a): **A.** (0-6 months), atlas and proximal radius; **B.** (6-12 months), distal humerus, scapula (glenoid), pelvis (acetabulm); **C.** (12-18 months), proximal first and second phalanx; **D.** (18-30 months), distal tibia and distal metapodials; **E.** (30-48 months), calcaneum, proximal and distal femur, distal radius, proximal tibia, proximal ulna; **F.** (>48 months), proximal humerus.
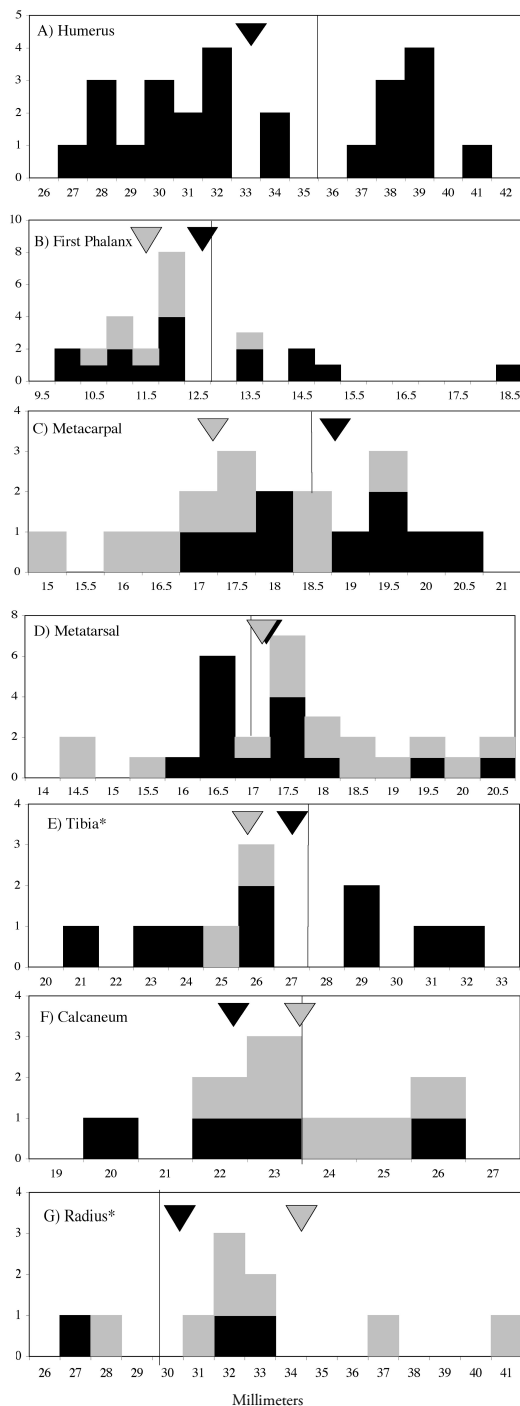
'Ain Jammam is relatively low, with only c. 40% of animals surviving beyond 18 months of age (Fig. 7). Male survivorship drops again for animals aged between 30 to 48 months, down to c. 20%. In contrast, female survivorship remains high, with most animals surviving beyond 18 months and c. 73% surviving past 30 months. Extremely small sample size (n = 3) prevents computation of female survivorship beyond age group D.

Metrical data for individual sheep indicate weakly bimodal or unimodal size distributions in several skeletal elements (Fig. 8). The lack of strong bimodality seen in sheep size distributions are due in part to the high degree of overlap in body size between male and female sheep (Davis 1996), an under-representation of large males in the assemblage, or both. Demographic profiles calculated for male and female sheep indicate lower survivorship for male sheep relative to female sheep (Fig. 7). Approximately 80% of males survive beyond 18 months, and are harvested at even greater intensities at 30 months, with only 45% of animals surviving beyond this age. Female sheep are slaughtered at relatively low intensities within each age group.

GAZELLA SP.

Gazelle remains are commonly encountered in the 'Ain Jammam faunal assemblage and comprise approximately 12.5% of the total assemblage (Table 3). Gazelle are a key component of several Late PPNB subsistence economies, including those of 'Ain Ghazal, Basta, and Ba'ja, sites at which gazelle were exploited at intensities similar to those seen at 'Ain Jammam (Becker 1991, von den Driesch & Wodtke 1997, von den Driesch *et al.* 2004).

The gazelle bones recovered from 'Ain Jammam represent one or more of the three different species indigenous to the southern Levant, including mountain gazelle (*Gazella gazella)*, goitered gazelle

FIG. 6. — Size distribution data for goats from 'Ain Jammam in order of epiphyseal fusion: **A.** distal humerus *Bd*; **B.** first phalanx *Bd*; **C.** distal metacarpal *DVL/DEL*; **D.** distal metatarsal *DVL/DEL*; **E.** Tibia *Bd*; **F.** calcaneum *GB;* **G.** distal radius *Bd.* Black bars indicate fused specimens. Grey bars indicate unfused specimens. Solid line indicates likely division between male and female animals. Asterisk indicates that the likely division between male and female animals is based on metrical data collected from modern wild goats (Zeder 2001).
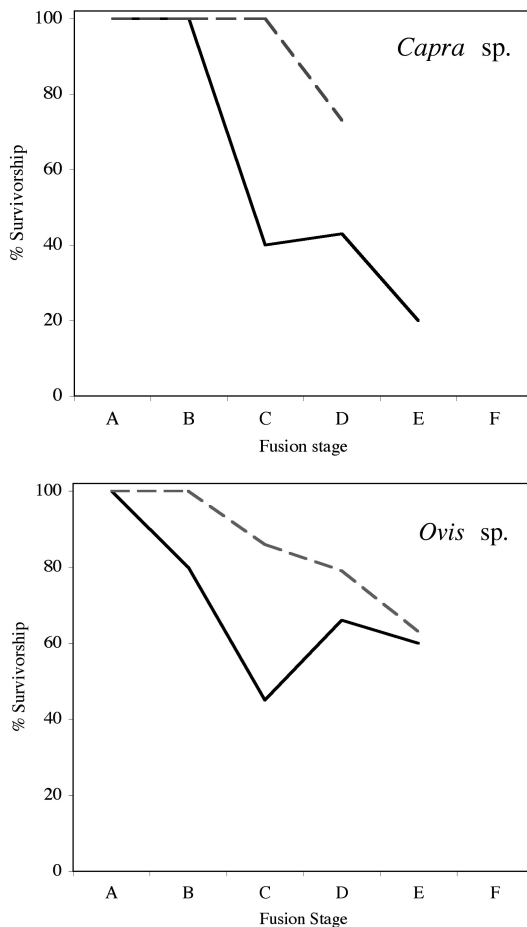
FIG. 7. — Male and female survivorship for 'Ain Jammam goats (n = 129) and sheep (n = 97) according to epiphyseal fusion. Black line = male, grey dashed line = female. Age groups defined by Zeder (2006b).

FIG. 8. — Size distribution data for sheep from 'Ain Jammam in order of epiphyseal fusion: **A.** distal humerus *Bd*; **B.** first phalanx *Bd*; **C.** distal metacarpal *DVL/DEL*; **D.** distal metatarsal *DVL/DEL*; **E.** Tibia *Bd*; **F.** calcaneum *GB;* **G.** distal radius *Bd*. Solid line indicates likely division between male and female animals.

(*G. subgutturosa),* and/or dorcas gazelle (*G. dorcas)* (Martin 1998, 2000). The three species are parapatric, with *G. gazella* inhabiting relatively moist grasslands and forested environments, *G. subgutturosa* preferring open steppes, and *G. dorcas* largely limited to deserts. Mountain gazelle and goitered gazelle were exploited at nearby Basta (Becker 1991). Mountain gazelle and dorcas gazelle are identified in the 'Ain Jammam assemblage on the basis of horn core morphology and metrical data. Each gazelle group exhibits broad body size differences, with *G. dorcas* being the smallest and most gracile species and *G. subgutturosa* the largest and most
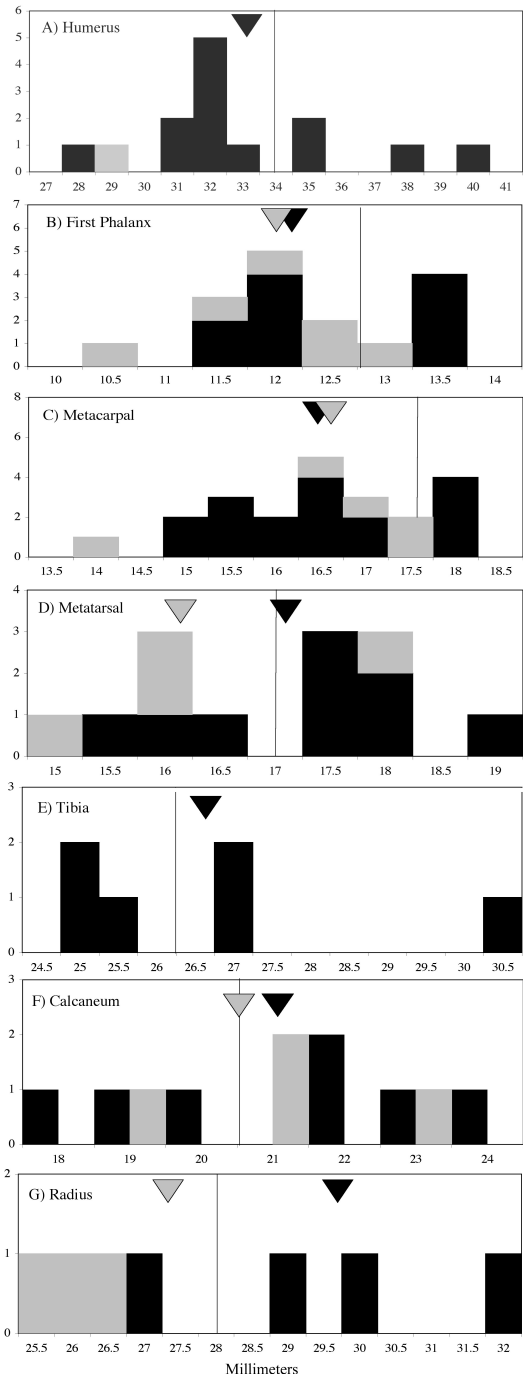
TABLE 3. — Epiphyseal fusion data for 'Ain Jammam gazelle. Approximate animal age at fusion according to Davis (1980).

Gazella sp.			
	Age at Epiphyseal Fusion	Fused	Unfused
Px Radius	c. 2 months	2	0
Ds Humerus	c. 2 months	5	0
Total >2 months		**7**	**0**
Scapula	3-6 months	15	2
Ph 1	5-8 months	28	0
Total >3-8 months		**43**	**2**
Ds Tibia	8-10 months	2	2
Total > 8-10 months		**2**	**2**
Px Femur	10-16 months	6	0
Calcaneum	10-16 months	3	1
Ds MC	10-16 months	6	1
Ds MT	10-16 months	4	0
Ds Femur	10-18 months	4	0
Px Humerus	10-18 months	2	0
Px Ulna	10-18 months	0	0
Px Tibia	10-18 months	0	0
Px Radius	10-18 months	0	2
Total >10-18 months		**25**	**4**

FIG. 9. — Size distribution data for gazelle fused metacarpals (Bd) from 'Ain Jammam (n = 9). Comparative metrical data from Compagnoni (1978); Bar-Oz *et al.* (2004); and Peters (1986).

FIG. 10. — Size distribution data for gazelle fused first phalanges (GLpe) from 'Ain Jammam (n = 19). White and black dots indicate mean and standard deviation of Glpe measurement for modern female and male *G. gazella*, respectively (Tchernov *et al.* 1990).

robust (Harrison 1968, Becker 1991, Helmer 1991: fig. 5). Gazelle also exhibit sexual dimorphism in body size, and for some skeletal elements, it is possible to metrically separate the bones of male and female animals, although some overlap between the two groups is expected (Tchernov *et al.* 1990, Bar-Oz *et al.* 2004).

In order to determine if hunters were exploiting multiple gazelle species at 'Ain Jammam, distal breadth (Bd) and greatest length (GLpe) measurements were taken from fused metacarpals and first phalanges and compared with metrical data obtained for modern mountain, dorcas, and goitered gazelle specimens (Figs 9 & 10). 'Ain Jammam gazelle metacarpals (n = 9) exhibit a wide range in distal breadth values that, together, encompass the entirety of metrical variation observed in all three modern gazelle populations. The majority of 'Ain Jammam gazelle bones, however, fall within the
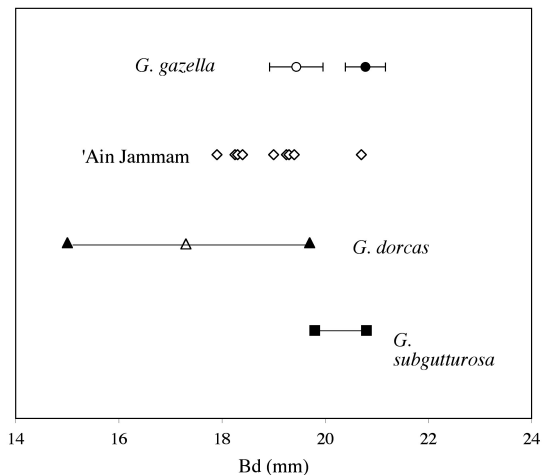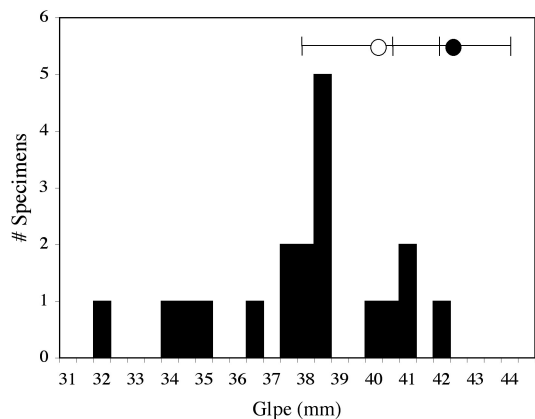
metrical ranges exhibited by the largest *G. dorcas* specimens and female *G. gazella*. Similarly, size distribution data for first phalanges also suggest several gazelle groups are represented in the 'Ain Jammam assemblage (Fig. 10). The bones on the large end of the size scale overlap in size with the smallest modern male mountain gazelle and

female mountain gazelle, with a high proportion of 'Ain Jammam first phalanges falling well below the smallest female mountain gazelle. The two distinct modes at 38.5mm and 41.0mm observed in 'Ain Jammam gazelle each fall within one standard deviation of the modern male and female standards and suggest male and female *G. gazella* are represented in the 'Ain Jammam assemblage. Despite the absence of comparative metrical data for the first phalanx of modern *G. dorcas* and *G. subgutturosa*, it is likely the third mode at 34.0-35.0 mm represents small-bodied *G. dorcas* and not the larger-sized *G. subgutturosa*. Dorcas gazelle exhibit consistently lower metrical values in several dimensions relative to *G. subgutturosa*, and, size ranges for each species exhibit little, if any, overlap (Helmer 1991: fig. 4). Although the presence of *G. subgutturosa* in the 'Ain Jammam assemblage cannot be entirely ruled out, the metrical data, along with two horncores identified as belonging to mountain gazelle, suggest that *G. gazella* and *G. dorcas* were the primary gazelle taxa exploited at 'Ain Jammam. The overwhelming majority gazelle bones recovered from 'Ain Jammam were fully fused (c. 98%), but the low representation of unfused skeletal parts in the assemblage is likely due in part to poor bone recovery methods rather than the use of a hunting strategy that focused exclusively on adult animals at 'Ain Jammam.

BOS SP.

Cattle are the third most commonly represented mammal at 'Ain Jamman, representing 8% of bone specimens identified to genus level in the assemblage (Table 2). Although a relatively small proportion of cattle were exploited at 'Ain Jammam, the high meat yields produced by individual animals suggests that cattle were a valuable component of the animal subsistence economy. Cattle may have held greater importance in the 'Ain Jammam subsistence economy compared to those of other Late PPNB sites in the region. Cattle bones comprise approximately 2% and 4% of identified material at Ba'ja and Basta, respectively, although these percentages are based on the sum of all identified remains recovered in each assemblage (Becker 1991, von den Driesch *et al.* 2004).

TABLE 4. — Epiphyseal fusion data for cattle from 'Ain Jammam according to Horwitz (2003).

Ain Jammam *Bos* sp.			
Age at Fusion		Fused	Unfused
9 mo.	Scapula	1	0
15 mo.	Ds Humerus	0	1
18 mo.	Ph 1	2	3
21 mo.	Metapodials	0	3
39 mo.	Calcaneum	0	1
42 mo.	Px Femur	0	1
45 mo.	Px Ulna	0	1
	Pelvis	1	0

TABLE 5. — Tooth wear stages for cattle from 'Ain Jammam according to Grant (1982).

Bos sp. Tooth Wear			
M/1	M/2	M/3	dp4
			N
A			
	B		
		G+	
		G+	
G			
	G	M	
	G		
	K		

Cattle bones from 'Ain Jammam are highly fragmented so that few epiphyseal fusion, tooth wear, and metrical data are available for the assemblage. Juvenile, adult, and very old adult animals are represented by both bone and tooth specimens (Tables 4 and 5). Although small sample sizes do not permit computation of survivorship curves, epiphyseal fusion data suggests a moderate kill-off of juvenile cattle, with 71% of bones displaying unfused epiphyses. However, tooth wear data indicates a predominance of older individuals *i.e.* mandibular molars exhibiting tooth wear stages 'G' or greater. LSI values, standardized against a wild, female cow from Ullerslev (Degerbøl 1970), indicate most 'Ain Jammam cattle are relatively small, although
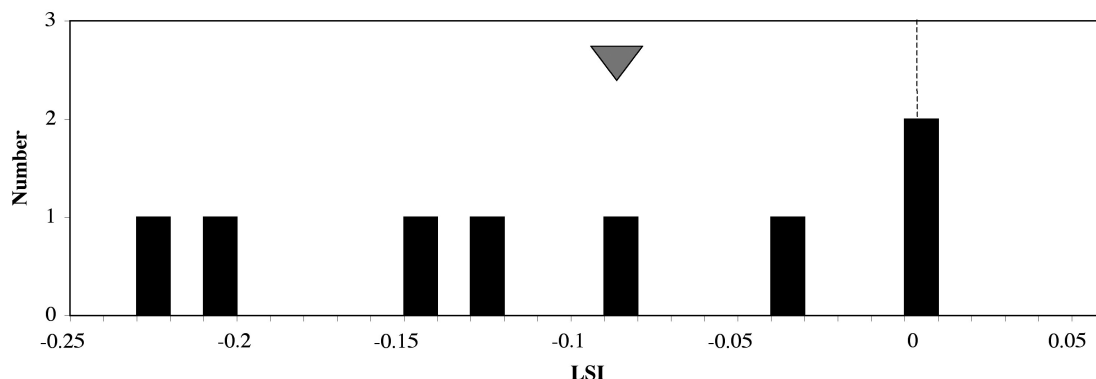
Fɪɢ. 11. — LSI distribution for *Bos* from 'Ain Jammam. Grey triangle = mean value.
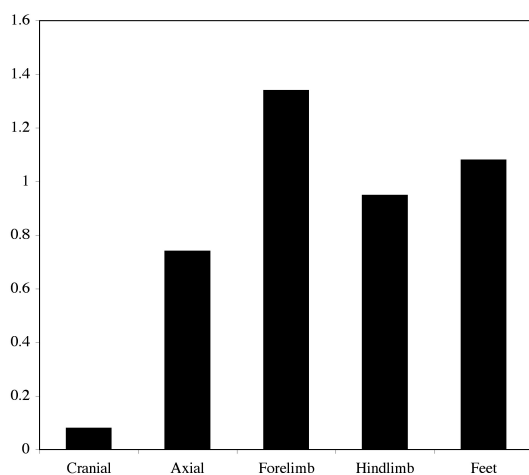

Fɪɢ. 12. — Deviations from the expected frequencies of animal regions in a complete skeleton for cattle at 'Ain Jammam (n = 75). Horn core fragments (n = 14), were not included in analysis.

some animals are similar in body size to the wild female standard (Fig. 11).

Cattle skeletal part representation data, presented as deviations from the expected frequency of skeletal parts in a complete ungulate skeleton for various anatomical regions, are presented in Figure 12. Deviation values were calculated by determining the minimum number of skeletal elements (MNE), standardizing the MNE against the number of elements present in the cattle skeleton *i.e.* MAU, and then standardizing again for each anatomical region *i.e.* forelimb region, axial region, etc. At

'Ain Jammam, cattle cranial parts are represented at levels expected in a complete carcass, while all axial, forelimb, hindlimb, and foot parts are all highly over-represented. Since the carcasses of large mammals are difficult to transport, the presence of skeletal parts from an entire large mammal carcass in a bone assemblage suggests exploitation of easily accessible, managed animals butchered at or very near to the site, while an under-representation of low utility skeletal parts such as heads and feet may indicate an exploitation strategy focused on a hunting animals located far away from a settlement site (Perkins 1969, Becker 2002). The over-representation of cranial elements and low-utility foot bones, may indicate that cattle carcasses were processed near 'Ain Jammam and suggests that at least some of the cattle exploited at the site were managed by humans.

EQUUS SP.

Equids, likely steppe-dwelling *Equus hemionus* (onager) and/or *Equus africanus* (wild ass), were also occasionally exploited at 'Ain Jammam. Low frequencies of both species have been identified at Basta, Ba'ja and 'Ain Ghazal (Becker 1991, von den Driesch & Wodtke 1997; von den Driesch *et al.* 2004). Bone specimens exhibiting ageing information include a single deciduous tooth, a fused distal radius, a fused first and second phalanx, and a fused third metapodial. Measurements recovered from a distal metatarsal (Bd = 37.8mm) and a fused second phalanx (Bp = 39.9mm, Bd = 34.6mm,

GL = 34.6 mm) fall within the metrical range of *E. africanus*.

OSTEICHTHYES

Although fish were routinely exploited at PPNB/C settlements located on the Mediterranean coast (Galili *et al.* 2002), evidence for the consumption of marine or freshwater marine resources at inland PPNB sites the southern Levant is unknown. Despite insufficient sieving of excavated deposits at ‘Ain Jamman, fish remains (4%) were recovered from multiple loci across the site. Approximately half of the ‘Ain Jammam fish remains were unidentifiable vertebral parts and bone fragments, while the remaining fish skeletal parts were identified as *Scarus* sp. (Table 6). The parrot fish is native to the Red Sea, and its presence at ‘Ain Jammam constitutes the earliest evidence for the use of Red Sea fish in the southern Levant (van Neer *et al.* 2004). Significantly, the moderately large distance between ‘Ain Jammam and the Red Sea (~150km) suggests that the fish were preserved, perhaps by smoking or salting, in order to prevent putrification during transport.

OTHER ANIMAL TAXA

Additional mammalian taxa native to a variety of ecotones were also exploited at ‘Ain Jamman and, together, make a substantial contribution (c. 7%), to the animal subsistence economy (Table 2). Ungulate taxa hunted at ‘Ain Jammam include *Dama* sp., *Capreolus* sp., and *Sus* sp. Fallow deer is represented by a single third phalanx. Roe deer are represented by an antler, two fused proximal femurs, an unfused distal femur, a fused first phalanx (Bp = 8.3mm, Bd = 7.1mm, GLpe = 37.2mm), the fused glenoid fossa of a scapula (Glp = 22.9mm), and another glenoid fossa exhibiting an indeterminate state of epiphyseal fusion. The marginal use of pig at ‘Ain Jammam, whose bones are represented only by a fragmented mandible, fragmented canine, and a rib head, likely reflects low densities of moisture-dependent porcine populations in the arid Ras en Naqb area.

Carnivore remains are also represented in the ‘Ain Jammam faunal assemblage. Fox (*Vulpes* sp.) remains comprise c. 2% of the total assemblage and are represented by skeletal parts from the forelimbs,

TABLE 6. — Taxonomic distribution and skeletal part representation for fish from ‘Ain Jammam.

Ain Jammam Fish Remains		
UNIDENTIFIED		
	Vertebrae	5
	Fragment	20
FAMILY SCARIDAE		
Scarus sp.	Quadrate	1
	Pharyngeal	1
	Parasphenoid	1
	Brancialstegal rays	5
	Rays	4
	Lateral facial	3
	Opercle	2
	Upper Pharyngeal	1
	Hyomandibular	1
Total NISP		**44**

hindlimbs, and extremity regions, suggesting that the inhabitants of the site exploited fox for their meat as well as their fur. Dog or wolf (*Canis* sp.) is represented by a third metacarpal, a fused first phalanx, a fused distal radius, an ulna, and a fused lumbar vertebrae. *Felis* sp. is represented by a single carnassial tooth.

Hares (*Lepus* sp.) are represented by skull, hindlimb, and forelimb elements. Tortoise carapace fragments (n = 2) were identified in the ‘Ain Jammam assemblage, as well as five unidentified bird fragments. A single mandible belonging to a rock hyrax (*Procavia* sp.) is also present in the assemblage.

DISCUSSION

The faunal data from ‘Ain Jammam provides a picture of herding and hunting strategies employed at a large, aggregate settlement during the Late PPNB. Since high-resolution analyses of faunal data describing animal exploitation practices from the latest portion of the Pre-Pottery Neolithic B are relatively few, particularly for sites located in central and southern Jordan, the data from ‘Ain Jammam provide an important source of new information concerning caprine husbandry practices, cattle management, and wild animal exploitation in the region.

CAPRINE EXPLOITATION AT 'AIN JAMMAM

Comparative LSI data suggests that the inhabitants of 'Ain Jammam exploited small-bodied, likely domesticated goats, and hunted some wild goats, either *Capra aegagrus* or *C .ibex*, as well. On average, 'Ain Jammam goats are smaller than managed, but morphologically wild, goats from Middle PPNB Abu Ghosh, as well as goats representing both domesticates and wild animals from Basta and Ba'ja. Although size diminution is not an appropriate 'leading edge' marker for identifying initial human management of animal herds (Zeder 2006b), reduction in body size associated with domestication processes is expected to occur over extended timescales as managed animal populations are exposed to a suite of anthropogenic selective pressures (Uerpmann 1978, Meadow 1989, Peters *et al.* 2005). Since goat domestication processes were initiated in the southern Levant during the Middle PPNB (Horwitz *et al.* 1999, Horwitz 2003), at least 500 years before 'Ain Jammam was occupied, it is likely that small sized goats at 'Ain Jammam represent domesticated animals. The higher proportion of smaller goats at 'Ain Jammam relative to the roughly contemporaneous sites of Basta and Ba'ja may reflect a herding strategy that focuses on maintaining a large number of female animals, a decrease in the importance of wild goat exploitation, or differences in the intensity of selection pressures favoring smaller animal body size.

Given that wild sheep populations likely did not inhabit central and southern Jordan during the early Holocene, the wide range in body size exhibited by 'Ain Jammam sheep, as well as animals from other Late PPNB sites in the region, is somewhat surprising. Although it is possible that some of the largest specimens identified as sheep belonged to *C. ibex*, it is equally possible that the largest sheep at 'Ain Jammam are heavy-bodied, domestic rams. The wide variation seen in the sampled sheep population may be due in part to the inclusion of both length and breadth measurements in the calculation of LSI values. Alternatively, founder populations of domesticated sheep, which either diffused to the southern Levant or were intentionally imported from the north, may have been characterized by high variation in body size.

In the southern Levant, the Late PPNB represents the first use of both domesticated sheep and goats by human groups that had previously relied on hunted gazelle and managed goats to meet their animal subsistence needs (Horwitz *et al.* 1999). The use of mixed caprine herding to the 'Ain Jammam subsistence economy diversified and almost certainly increased the flexibility of animal exploitation systems available to herder-hunters during a period when new pressures on available plant, animal, and land resources likely heightened in response to increasing anthropogenization of the landscape, density of built environments, and possibly curtailing of territories. It is well-known that sheep and goats exhibit different feeding behaviors, have distinct physiologies, and yield disparate quantities of ante- and post- mortem animal products. Pastoralists routinely exploit these dissimilarities in caprine physiology and production by developing and applying husbandry practices designed specifically for each animal in order to extract amounts of meat, hair, and milk necessary for meeting short-term subsistence needs, as well as shape herd composition for future social and economic goals. Manipulation of the timing and intensity of sheep and goat harvesting is a centrally important and highly malleable management strategy that imparts immediate effects on herd productivity and, is a husbandry practice highly visible in the archaeofaunal record. Differential kill-off strategies for sheep and goat feature prominently in agro-pastoral animal exploitation systems in the present and in the past, yet our understanding of sheep- and goat- specific harvesting practices employed in the southern Levant during the Late PPNB is remarkably poor.

The faunal assemblage from 'Ain Jammam provides valuable, previously undocumented, information concerning kill-off of sheep and goats during the Late PPNB. The combination of differences in sheep and goat abundances and divergent harvesting strategies enacted on each taxon suggest 'Ain Jammam herders manipulated each animal group differently and likely maintained distinct production goals for each animal group. The slightly higher abundance of goats over sheep (1 goat: 1.3 sheep) at 'Ain Jammam is likely due to a combination of factors, including pastoral production goals, local environmental conditions, and the addition of sheep, a novel animal

technology, to the Late PPNB subsistence complex. Goats have higher reproductive rates and produce higher quantities of milk compared to sheep and, are also better adapted to marginal environments, exhibit decreased mortality and are able to produce relatively high amounts quality animal product under poor grazing conditions (Redding 1981). Caprine herds containing a higher proportion of goats are therefore better suited to buffer against unpredictable fluctuations in local environmental conditions and serve to reduce overall risk to the animal subsistence base. This security feature may have been particularly important at 'Ain Jammam, where the nutritional and breeding requirements of recently imported sheep may have not yet been completely familiar to herders. At 'Ain Ghazal, sheep are not relatively more abundant than goats until the PPNC (Wasse 2002), suggesting that herders had not fully developed sheep management strategies that consistently accommodated the different physiological needs of sheep until the end of the Late PPNB. Similarly, the general pattern of high survivorship in sheep compared to goats may be due to use of a management strategy that emphasized conservation of valuable ovine resources. Sheep may have been lightly harvested by 'Ain Jammam herders in order to preserve animals that were still a relatively new addition to the southern Levantine PPNB subsistence complex.

Until quite recently, the exploitation of bovids for their milk was thought to be relatively late addition to Near Eastern pastoral subsistence systems, a technological innovation that emerged sometime during the Early Bronze Age (Sheratt 1983.). There is increasing biomolecular and demographic and evidence, however, suggesting that dairying practices were in use at least by 6500 cal B.C. in northwest Anatolia during the Pottery Neolithic and may have emerged as early as the Middle PPNB in the northern Levant (Vigne & Helmer 2007, Evershed *et al.* 2008). In the southern Levant, research suggests that caprine herds were not exploited for their milk until much later in prehistory, during the Chalcolithic or Early Bronze Age (Grigson 1995). Indeed, several researchers suggest, on the basis of comparative demographic analyses of archaeofaunas and Payne's production models, that Late PPNB caprines were utilized solely for their meat resources

(von den Dreisch & Wodtke 1997, Wasse 2002, Becker 2004).

At 'Ain Jammam, the combination of moderate kill-off of very young animals up to six months in age, extended survivorship of female sheep and goats, and increased kill-off of caprines at mandibular wear stages F and G, as well as female sheep and goats older than 30 months, suggests that caprines were exploited in part for their milk at low levels (Figs 4, 5, 7 and 9). Although intensive kill-off of young males is generally projected for herds exploited for dairy so that herders may increase the availability of milk for their own consumption (Payne 1973), new models suggest that intensive slaughter of lambs and kids is not necessary if milk production is the exploitation goal. Instead, young male animals may be lightly harvested and adult females culled when their productivity levels begin to drop (Vigne & Helmer 2007).

It may be that 'Ain Jammam herders exploited caprines for their milk at higher intensities, but identification of elevated young animal kill-off associated with heightened milk production is likely obscured by severe under-representation of fragile infant- and juvenile- aged bones of young animals 'Ain Jammam assemblage (see earlier discussion). Accidental inclusion of wild *Capra ibex* bone specimens in survivorship curves would likely also obscure harvesting strategies oriented toward milk production. Generally, although not always, hunters target mature animals and large males in order to maximize meat extraction from wild ungulate populations (Hesse 1982). If individual goat bone specimens entered the 'Ain Jammam assemblage through a prime-aged adult hunting strategy, it is likely that caprine survivorship curves will be slightly skewed towards older kill-off.

Evidence for differential application of milk exploitation strategies on separate sheep and goat herds is unclear. Initially, it appears that there is high kill-off of very young male sheep and prolonged survivorship in the very youngest male goats, but low sheep survivorship observed in this critical age group (Fusion Group A) could be due to small sample size rather than actual herder decision-making favoring intensive slaughter of very young animals. The pattern of relatively high kill-off of juvenile sheep for animals aged between 6 and 12 months,

while goats of the same age exhibit high survivorship, however, suggests that 'Ain Jammam herders were slaughtering a higher proportion of male sheep relative to male goats, either to reserve more milk for their own use or for their tender meat (Vigne & Helmer 2007).

Divergences in survivorship seen in female sheep and goats may have to do with differences in management strategies, other than harvesting, applied to each caprine group. Since ewes generally do not begin lambing until their second year (Redding 1981), it seems unlikely that a harvesting strategy focused on elevated kill-off of female sheep aged between 12 to 18 months, a slaughtering schedule that would significantly weaken the reproductive base sheep populations, was in use at 'Ain Jamman. Instead, an animal management strategy that involved mobilization of some animals might explain the lower frequencies of yearling female sheep. Unlike goats, which were commonly exploited and managed throughout the southern Levant for hundreds of years preceding the Late PPNB, sheep represent a new, additive technology to local subsistence systems. Although relatively abundant at larger, arguably 'centrally' located settlements such as 'Ain Jamman (*e.g.* Gebel 2004) sheep may not have been readily available, at least initially, to herders inhabiting smaller settlements or camps. It may be that reproductively valuable female sheep from large settlements such as 'Ain Jammam were traded out in order to serve as 'seeds' for founder herds elsewhere. Further data documenting sheep abundances and demography, as well as additional, high-resolution radiocarbon dating of Late PPNB settlements throughout the southern Levant are necessary in order to further test this hypothesis.

Although it appears that the inhabitants of 'Ain Jammam engaged in low-level milk production, 'Ain Jammam herders primarily employed harvesting strategies that focused on obtaining meat from caprines at sustainable levels. Mortality data for 'Ain Jammam caprines indicates high-kill off of juvenile animals one to two years in age in survivorship curves computed using both tooth wear and epiphyseal fusion data (Figs 4 and 5). Herders pursuing meat production intensively slaughter juvenile males while retaining reproducing females in order to optimally balance animal weight gain

with food resource availability (Payne 1973, Vigne & Helmer 2007). Often, pastoralists further tune the timing of juvenile male slaughter in order to exploit differences in the qualities of meat produced by animals and distinguish between animals between yearlings, which yield tender meat, and slightly older juveniles, which produce tougher, but higher volumes, of flesh (Vigne & Helmer 2007). The slight decrease in survivorship for 'Ain Jammam caprines aged between 6 and 12 months may be indicative of 'tender meat' extraction (Meat Model B; Vigne and Helmer 2007), but an exploitation strategy focused on extracting the maximum amount of milk produced by lactating females would likely produce a similar survivorship curve as well. Although kill-off of 'Ain Jammam caprines is considerably lower than expected for Payne's optimized meat model and is suggestive of a conservative, mixed-use herding strategy, it is clear that a high proportion of post-mortem products were obtained from those animals that had attained an optimal body weight.

GAZELLE EXPLOITATION

The relatively high abundance of gazelle in the 'Ain Jammam assemblage indicates that the animal served as an important meat resource that supplemented foodstuffs obtained from domesticated caprines. Gazelle appear to have been hunted on a seasonal basis at 'Ain Ghazal (von den Dreisch & Wodtke 1997), and a similar scheduled gazelle exploitation system may have been in use at 'Ain Jammam as well. Poor recovery methods have likely reduced the visibility of small, unfused gazelle bones at 'Ain Jammam, but the exploitation of animals younger than 10 months may indicate that gazelle were hunted during the summer and autumn months (Table 3). By extracting meat from gazelle during these months, herders have greater latitude to schedule the caprine harvest during time periods when it more optimal to do so, or delay caprine harvesting altogether in order conserve animal resources.

The importance of gazelle in the 'Ain Jammam subsistence economy may be rooted in earlier subsistence traditions. Gazelle formed the primary constituent of most earlier PPN and Natufian southern Levantine animal-based subsistence economies (Tchernov 1995, Horwitz *et al.* 1999), and their continued

use during the Late PPNB may be have taken on cultural significance as well as serving economic role. The ritualized use of gazelle at 'Ain Jammam should be cautioned against. A gazelle skull placed in a wall niche located in a moderately-sized room is described by Waheeb and Fino (1997), but it is unclear if the skull was placed within the niche in prehistory.

CATTLE EXPLOITATION AT 'AIN JAMMAM

There is increasing evidence for early human management of taurines in the northern Levant during the Early PPNB, including size diminution in male cattle and transport of cattle to Cyprus (Vigne *et al.* 2003, Peters *et al.* 2005). Unfortunately, our understanding of cattle domestication processes and the use of managed cattle in the southern Levant in the PPNB remains unclear due to the low frequencies and high fragmentation of cattle remains in faunal assemblages from the region. It may be that domesticated animals diffused from the north into, or were intentionally imported to, the southern Levant during the Late PPNB (Becker 2002, Peters *et al.* 2005), or, the southern Levant served as an independent center for cattle domestication processes (Becker 2002, Horwitz & Ducos 2005).

Although the 'Ain Jammam data do little to clarify the exact processes by which domesticated cattle came into use in the southern Levant, the presence of both very large, aurochsen- and smaller- sized cattle, moderate kill-off of juvenile animals, and over-representation of cranial and foot skeletal parts suggests that at least two different cattle exploitation systems were employed at 'Ain Jammam: one centered around hunting wild aurochs and another focused on managing cattle. Both managed and wild cattle share the same asset of providing immediate, substantial packages of meat, blood, fat, and skins, products that may have been preserved for long-term storage or distributed between households for more immediate consumption. By simultaneously manipulating two alternative, but complementary, cattle use systems, 'Ain Jammam herders diversified their taurine resource base and reduced potential risks associated with the first use of husbanded cattle. Although herders may have accrued a significant body of pastoral knowledge from herding goats, a

subsistence activity that had already been in use in the southern Levant for approximately 500 years, the highly different physiology of and nutritional requirements for cattle may have initially posed significant management challenges. By sustaining wild aurochs hunting, herders could continue experimentation with managing imported or locally domesticated cattle without endangering access to the large packages of post-mortem products provided by these animals. Wild cattle may have also served as a readily available propagation pool which could be dipped into regularly in order to replenish managed herds (Becker 2002). Alternatively, it may be that cattle management and aurochs hunting were highly canalized exploitation systems that served entirely separate socio-economic functions, with husbanded animals used for mundane, everyday subsistence reasons while aurochs were exploited for specialized purposes. Aurochs consistently appear and feature prominently in many Pre-Pottery Neolithic ritual contexts throughout the Near East (Hauptmann 1993; Horwitz & Goring-Morris 2004), and, aurochs bones likely representing the remnants of feasting events have been identified at several PPNB sites in the southern Levant, including Kefar Hahoresh and Basta (Becker 2002, Horwitz & Goring-Morris 2004). Wild cattle may have been harvested primarily for specialized events, feasting, ritual, or otherwise, at 'Ain Jammam, although additional contextual data are necessary in order to further test this hypothesis.

CONCLUSION

Southern Levantine Late PPNB animal-based subsistence economies have long been conceptualized as necessarily pastoral, where the production of meat through sheep and goat herding is required in order to sustain human populations inhabiting densely built aggregate settlements, with hunting playing only a minor role in the subsistence economies of these large settlements. New faunal data from 'Ain Jammam, however, suggests this characterization of animal exploitation systems in use during the latest Pre-Pottery Neolithic is quite narrow, and that some Late PPNB animal exploitation strategies are better understood as consisting of an array of highly

complex herding activities intertwined with both scheduled and opportunistic hunting practices. Demographic and metrical data recovered from the 'Ain Jamman faunal assemblage suggest a complex array of animal use practices were in use at the site, including intensive caprine herding, multi-faceted animal harvesting systems, and experimentation with managing cattle while retaining animal use strategies rooted in earlier Pre-Pottery Neolithic subsistence systems. In addition to staggering the harvest of male and female caprines, as well as possibly exploiting caprines for their milk at low levels, herder-hunters may have scheduled the hunting of gazelle according to the timing of the caprine harvest and engaged in opportunistic capture of an array of wild animals that together, made a substantial contribution to the diet.

The retention of gazelle hunting, a central feature of earlier PPN and Natufan subsistence economies, in the overall 'Ain Jammam animal exploitation system may have helped provide a familiar and stable fall-back resource upon which herder-hunters could access regularly as they experimented with developing new caprine harvesting strategies. The exploitation of multiple wild animal taxa from diverse ecotones at 'Ain Jammam and the expansion, either directly or through trade, of animal exploitation systems into new ecological niches *i.e.*, marine environments, has important implications for understanding potential constraints on natural resource availability during the Late PPNB. Herder-hunters may have pursued wild game as a buffer resource that reduced their overall subsistence risks, but increased anthropogenization of landscapes may have led to the development of exploitation systems that included use relatively high energy cost, low-return animal taxa including fish from the Read Sea and sparsely distributed dorcas gazelle. It is likely that the importance of small game such as hare, birds, and tortoise in the 'Ain Jammam subsistence economy was much greater than the abundance data indicate, but poor bone recovery methods have greatly obscured this portion of the subsistence economy virtually invisible.

At its core, the complex animal exploitation system employed at 'Ain Jammam represents an entirely new approach to subsistence in southern Levantine prehistory – mixed caprine herding. In order to better understand the evolution of southern Levantine hunting and husbandry practices some 500-1000 years *after* domestication processes for sheep and goat were initiated, additional high-resolution analyses of faunas recovered from Late PPNB settlements are needed. Basic faunal recovery methods must be improved if animal exploitation strategies where high-kill off of immature animals is expected are to be detected. New analytical approaches, particularly light stable isotopic and ancient DNA analyses are critical to understanding and tracking the emergence of novel husbandry practices including foddering (Makarewicz & Tuross 2009), seasonality (Kirsanow *et al.* 2008), and weaning (Balasse & Tresset 2002). Through a combination of zooarchaeological and biomolecular approaches, we may better document and define how the emergence of complex caprine husbandry systems contributed to a shift in Late Pre-Pottery Neolithic B social organization towards increased social differentiation and use of private property.

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