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## **Faunal turnover in the Azraq Basin, eastern Jordan 28,000 to 9,000 cal BP, signalling climate change and human impact**

Louise Martin<sup>a, b, c</sup>, Yvonne H. Edwards<sup>a</sup>, Joe Roe<sup>a</sup>, Andrew Garrard<sup>a</sup>

<sup>a</sup>Institute of Archaeology, University College London, Gordon Square London WC1H 0PY:

<sup>b</sup>corresponding author: <sup>c</sup>[louise.martin@ucl.ac.uk](mailto:louise.martin@ucl.ac.uk)

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### **Abstract**

Recent zooarchaeological analyses of game exploitation in the Epipalaeolithic of the Southern Levant identify a decline in large game in the Natufian, with corresponding increase in small prey, interpreted as hunting pressure driven by population expansion. To date, studies focus on the Mediterranean zone. This paper adopts similar approaches to examine Epipalaeolithic to Neolithic faunal data from 16 sites in the steppic Jordanian Azraq Basin. Results here reveal very different trends. Large game, mainly equids, fluctuate throughout the Epipalaeolithic, due to climatic conditions and available water/vegetation. Cattle thrive in the Azraq oasis, showing no decline in the Late Epipalaeolithic. Gazelle exploitation is predominant and sustainable throughout the Epipalaeolithic, even at Kharaneh IV and Wadi Jilat 6 ‘megasites’. However, PPNB assemblages from the limestone steppe show intensive game exploitation resulting from longer-stay settlement. The focused gazelle-hunting camp at Dhuweila in the Basalt desert also shows pressure from indiscriminate culling impacting herd demography, interpreted as providing meat for onwards exchange. Human impacts on steppe fauna appear both local and in many cases short-term, unlike the large-game suppression reported from west of the Rift Valley. Resource pressures and game over-kill, whether population-driven or otherwise, are not currently apparent east of the Jordan River.

### **Keywords:**

Southern Levant; Epipalaeolithic; PPNB; Prey exploitation; Hunting pressure; Palaeoenvironment; Climate change

1 **Faunal turnover in the Azraq Basin, eastern Jordan 28,000 to 9,000 cal BP,**  
2 **signalling climate change and human impact**

3

4

5 **INTRODUCTION**

6

7 In recent decades, the southern Levant (modern day Jordan, southern Syria and Lebanon,  
8 Palestine territories and Israel) has been the focus of attempts to understand diachronic changes in  
9 the patterning of animal remains found at archaeological sites through the late Pleistocene and early  
10 Holocene. This area has yielded rich faunal datasets for the Epipalaeolithic and early Neolithic  
11 periods (24,000-9,000 cal BP), encouraging research agendas aimed at documenting and explaining  
12 zooarchaeological trends up to the appearance of agriculture and domestic livestock at approximately  
13 10,500 cal BP. The paramount theme examines the broadening exploitation of animal prey by  
14 hunter-gatherer-foragers across this period with attendant questions related to animal use  
15 intensification.

16 Zooarchaeological studies in the southern Levant have long noted an increase in smaller  
17 game, either in the Natufian (later Epipalaeolithic, c. 14,700-12,000 cal BP) or Pre-Pottery Neolithic  
18 A (PPNA, earliest Neolithic, c.12,000-10,900 cal BP) (e.g. Davis, 1985; Tchernov, 1991) attributed  
19 to longer-term occupation of settlement sites, and the construction of an ‘anthropogenic’  
20 environment less favourable to larger mammals (Tchernov, 1994; but see Edwards, 1989 and Henry,  
21 1989 for alternative explanations). Longer time-depth studies over the past 15 years have refined the  
22 picture of a broadening animal food spectrum in the Natufian, showing an increased representation of  
23 fast-moving game birds and hares on sites (Stiner et al., 1999; Stiner, Munro and Surovell, 2000;  
24 Stiner, 2001; Stiner and Munro, 2002; Munro, 2003, 2004) along with a decline in larger game  
25 animals (Stutz, Munro and Bar-Oz, 2009), and intensive hunting of the dominant small ungulate,

26 gazelle (Munro, 2009). These trends are widely accepted as resulting from expanding human  
27 populations exerting pressure on large game animals by over-hunting, which increasingly forced the  
28 exploitation of lower ranked small game animals and birds. In this paradigm, small game usage is  
29 interpreted as reflecting a ‘demographic pulse’ (Stiner, Munro and Surovell, 2000), an idea that has  
30 found widespread acceptance in the archaeological literature.

31 Zeder’s (2012) questioning of these interpretations of ‘broad spectrum’ patterns is a relatively  
32 lone voice, casting uncertainty on the general applicability of the framework. Drawing on case-  
33 studies where broad-spectrum expectations are not borne out, and developing an alternative view of  
34 optimal foraging based on niche construction by humans (NCT), she argues that apparent ‘resource  
35 depression’ need not be driven by population pressure or over-hunting. Rather it may have been a  
36 feature of resource rich environments, where ranges of habitats and seasonally predictable plant and  
37 animal resources could have encouraged longer term stay of human groups and stimulated different  
38 means of procuring smaller prey, with little impact on large mammals. She looks beyond core  
39 Levantine areas, for example to eastern Turkey, to find large game surviving well into the Holocene.  
40 Indeed even in the southern Levantine Jordan Valley the current authors find no evidence of resource  
41 pressure in one Natufian case-study (Edwards and Martin, 2013; P. Edwards et al., 2013).

42 The aim of this paper is to look beyond the lush Mediterranean woodland/parkland zones of  
43 the southern Levant to examine a sequence of Late Pleistocene/early Holocene faunal assemblages  
44 from the Azraq Basin of eastern Jordan. The basin encompasses a variety of environmental niches  
45 and has been intensively researched over the past 35 years; the archaeological sequence has gaps but  
46 nevertheless faunal data can be used to explore whether observed trends are similar to those in the  
47 Mediterranean zones. In brief, our research questions are: Is an increase in small game witnessed  
48 through the Epipalaeolithic in the Azraq Basin? Is there a corresponding decline in larger game? Is  
49 there evidence for hunting pressure? It should be borne in mind that the eastern Jordanian steppe and  
50 desert sites are likely to have been occupied only seasonally and populations may have been

51 relatively sparse through some stages of the Epipalaeolithic and early Neolithic, although year-round  
52 settlement might have been possible (Byrd et al., 2015). Some favoured locales appear to have been  
53 occupied longer-term or more intensively but the overall low density of sites does not suggest  
54 demographic ‘packing’; thus, the suggested ‘cause’ of broad spectrum economies elsewhere should  
55 not be applicable here. The eastern Jordan sequence can therefore, in some respects, serve as a ‘test’  
56 of factors involved in faunal spectrum change.

57 An associated aim of this study is to unravel whether changes in faunal spectra represent  
58 variable *availability* of wildlife, human pressures on wildlife, or selective hunting practices. The role  
59 of climate change, while acknowledged as a prime driver in cultural change through the  
60 Epipalaeolithic and Neolithic of the southern Levant (e.g. Bar-Yosef and Belfer-Cohen, 1989; Henry,  
61 1989; Byrd and Garrard, 1990; Goring-Morris and Belfer-Cohen, 1998; Byrd, 2005) tends to be  
62 underplayed in recent studies of faunal turnover (Stiner and Munro, 2002; Stutz, Munro and Bar-Oz,  
63 2009) where humans are given primacy as catalysts of change. We assume that relatively arid zones  
64 are sensitive to pressures arising from regional climate changes, which may lead to fluctuations in  
65 animal communities, and recognise that ecological pressures should be separated from human  
66 impacts where possible.

67

### 68 **The Azraq Basin – present climate, water and vegetation**

69 The Azraq Basin is an inland drainage system covering c. 12,000 km<sup>2</sup> of the eastern Jordanian  
70 plateau, with the Azraq oases at its centre (Figure 1). The area embraces a diversity of geological  
71 contexts and ecosystems with varied elevation from 500m in the basin centre to 1,800m at the  
72 northern periphery (Figure 2). The west and southern parts of the drainage system are typified by  
73 limestone, chalk and marl hills, cut through by wadis which feed into the low-lying central basin and  
74 eventually into the central playa at Qa el-Azraq. To the north and north-east the basin is covered by  
75 basaltic hills surfaced by extensive boulder fields (Figures 1 and 2). Although basalt is impermeable

76 it contains joints and fissures which allow rain to replenish the underlying water-table, supplying  
77 seasonal springs at the basalt fringes and eventually feeding the copious perennial springs at Azraq.  
78 Small seasonal pools can form in wadi systems in both the basalt and limestone areas after winter  
79 storms although rarely for more than a few weeks.

80         The Azraq Basin has a smaller seasonal and diurnal temperature range than the Arabian or  
81 North African deserts and the general climate is less arid but characterised by hot dry summers and  
82 by cold winters with occasional storms (Nelson, 1973; Garrard and Byrd, 2013, 10-17). Rain falls  
83 sporadically across the basin in winter and early spring, with average mean levels varying from  
84 c.200mm, in the north and western margins, to less than 50mm in the south and east. The temperature  
85 ranges between minus 4°C and 42°C. The area currently falls within the Irano-Turanian vegetation  
86 zone, with Sudanian elements penetrating to the south. Vegetation is generally wet-steppe, becoming  
87 more arid and desertic to the south and east. Along with abundant grasses, it includes a variety of  
88 chenopods such as *Atriplex* and *Salsola*, woody shrubs such as the *Retama* (Broom) and *Haloxylon*  
89 which provide some shade, and occasional *Pistacia* trees which provide both shade and fat-rich nuts.  
90 The Basalt desert has some additional specific shrubs such as the heat resistant *Lycium depressum*  
91 and *Capparis spinosa*, the caper bush. At the centre of the basin, the Qa el-Azraq is an area that  
92 floods after heavy winter storms although the standing water currently usually evaporates by the end  
93 of spring. Large permanent wetland areas also occupy the oasis, fed by copious perennial springs and  
94 surrounded by marshy vegetation dominated by bullrushes, giant reeds and *Tamarix* shrubs.

95         Wildlife in the basin has been greatly impacted by hunting with firearms from vehicles during  
96 the 20<sup>th</sup> century, so that large game such as gazelles and onagers are locally extinct. Shaumarai  
97 wildlife reserve at Azraq hosts reintroduced herds of Arabian oryx and gazelles, but otherwise the  
98 area serves as seasonal grazing lands for large sheep and goat flocks, with farming around Azraq, and  
99 some opportunistic rain-fed crop-sowing in some wadis (see France 2010, 85-116; Garrard and Byrd,  
100 2013). This is a very different picture to the prehistoric (and perhaps more recent) past when

101 numerous archaeological sites attested to wildlife-rich landscapes which underpinned hunter-gatherer  
102 use of the area.

103

## 104 **MATERIALS**

105         Since the late 1970's the Azraq Basin has been the focus of several survey and excavation  
106 projects (Baird et al., 1992; Betts, 1985, 1986, 1991, 1998; Betts et al., 2013; Byrd, 1988; Copeland  
107 and Hours, 1989; Garrard, 1998; Garrard et al., 1994a, 1994b, 1996; Garrard and Byrd, 1992, 2013;  
108 Muheisen, 1988; Muheisen and Wada, 1995; Rollefson et al., 2001; Richter et al., 2009, 2013, 2014;  
109 Maher et al., 2012). We consider sixteen sites in the Azraq catchment that have produced faunal  
110 assemblages, spanning a timeframe from the Late Upper Palaeolithic c.30 ka to the end of the Late  
111 PPNB c.9.0 ka cal BP. For the analyses that follow, it is important to note the variation in site types  
112 and environmental contexts. These are summarised in Figures 1 and 2 which show site locations, and  
113 Table 1 which presents site size, position and references. Ascribed occupation periods, radiocarbon  
114 dates and chronotypological assignments are given in Table 2. Sites fall into three broad  
115 environmental contexts: the oasis and springs in the central basin; valleys draining the rolling hills of  
116 the limestone steppe; wadis and playas cutting through or fringing the basalt steppe and desert. All  
117 sites can be assumed to have been occupied by mobile hunter-gatherers; Neolithic faunal  
118 assemblages with domestic livestock are not included here since pasturing would have affected wild  
119 animal procurement. Of the 16 sites, some exhibit signs of repeated or longer-term visits, while  
120 others seem to have been shorter-term camps. An estimate of these different occupation patterns is  
121 shown in Table 3 (developed from Byrd, 1988, based on lithic analyses and densities, bone densities,  
122 artefact distributions and thickness of deposits). Complex factors such as resource base, site function  
123 and social links are likely to have affected length of stay. Several sites exhibit multiple occupation  
124 levels representing distinct reoccupations of the same locale in different time-periods, often with a  
125 hiatus between them. In such cases faunal assemblages from these are considered separately (e.g.

126 Kharaneh IV, Wadi Jilat 6, Wadi Jilat 22; Dhuweila). Sites with different re-building phases within  
127 the same time-period, however, have their assemblages combined, e.g. Wadi Jilat 7 Middle PPNB  
128 assemblages. The total number of faunal assemblages used in the current study is 31 (Table 2).  
129 Since the aim of the study is to trace faunal change through time, we assume that each assemblage  
130 ‘samples’ the available fauna in the area. There is a notable absence of faunal data from the Latest  
131 Epipalaeolithic/Late Natufian period, reflecting the sparsity of known and excavated sites from this  
132 time-frame in the Jordanian steppe and desert until recently (Richter et al., 2014). The PPNA is  
133 currently unknown from this region (Byrd, 1992).

134 Faunal assemblages were originally recorded by various zooarchaeologists and many by the  
135 current authors (Table 1). The Numbers of Identified Specimens (NISP) for each assemblage are  
136 given in Table 4, alongside the relative proportions (NISP %) of taxa. All identified mammalian taxa  
137 are included, plus tortoise and bird remains.

138

## 139 **METHODS**

140 We follow methods devised by Stutz, Munro and Bar-Oz (2009) who explored changes in  
141 large to small prey through the Epipalaeolithic in the western Galilee/Mount Carmel region. Stutz  
142 and colleagues used the numbers of gazelle (often the most common species) as a reference index  
143 against which the relative abundance of other sized prey could be assessed, diachronically. They  
144 grouped other prey animals by body weight and their ‘escape speed’, e.g. either fast or slow  
145 (following approaches of Stiner, Munro and Surovell, 2000; Stiner, 2001; Stiner and Munro, 2002).  
146 This approach is used for the Azraq Basin assemblages and Figure 3 shows the resulting taxa groups.  
147 There is some variation in prey types between Galilee/Mount Carmel and Azraq Basin regions,  
148 however, which reflect different vegetation and ecological conditions. Deer, for example, are  
149 common in the Galilee/Mount Carmel sequence, where woodland abounds, whereas deer are absent  
150 altogether from Azraq Basin assemblages where equids and cattle constitute the main large game.

151 Medium-large game, such as boar and ostrich, are also relatively scarce in the Azraq Basin, but have  
152 been included in order to record this weight/size category.

153 Stutz and colleagues omitted counts of foxes, canid and martens from their Galilee/Mount  
154 Carmel study (Stutz et al., 2009; Munro, 2004) presumably being unsure of their status as prey  
155 animals. We include these taxa, along with larger birds, in the small game category for the Azraq  
156 sites, since there is no evidence to suggest they are not part of the prey assemblage. They are found  
157 amongst bones of larger prey showing similar treatment and condition and are clearly within the  
158 cultural assemblage. While the Galilee/Mount Carmel study encompassed the Epipalaeolithic, from  
159 earlier to late phases, our study looks back to the Late Upper Palaeolithic and forward to the PPNB,  
160 providing an extended view of prey change over time.

161 Following the approach described by Stutz and colleagues (2009), NISP count indices were  
162 used to define the relative abundance of four grouped prey types with categories divided by size and  
163 speed; fast small game (*fsg*; hare, fox, canids and medium/large birds); slow small game (*ssg*;  
164 tortoise, hedgehog, porcupine); medium-big game (*mbg*; ostrich, boar); large-big game (*lbg*; equid,  
165 cattle). While the taxa amongst these prey types often have different habitats, feeding ecologies and  
166 defence behaviours it is primarily their relative size and speed which are of interest here. This  
167 approach allows us to draw out regional comparisons with the Galilee/Mount Carmel area. Small-  
168 big game (*sbg*) largely gazelle, cf *Gazella subgutturosa*, with very occasional wild sheep/goat, were  
169 used as a reference index against which the relative abundance of large and small game were  
170 assessed [e.g. relative abundance index (RAI) =  $\text{NISP } lbg / (\text{NISP } lbg + \text{NISP } sbg)$ ]. This strategy  
171 avoids the false identification of abundance change in other prey types.

172

### 173 **Sample size analysis**

174

175 Sample sizes vary widely across the faunal assemblages shown in Table 4, with some NISPs in the  
176 thousands and others less than a hundred. It is well known that taxonomic abundances in an  
177 assemblage can be affected by sample size (Grayson, 1984, 116–129), so in order to screen for  
178 inadequate sampling we plotted the relationship between sample size and the relative abundance  
179 indexes (RAIs) of our four prey type groups (Figure 4). With the exception of *mbg*, none of the RAIs  
180 showed a significant correlation with sample size, validating our assumption that variation in these  
181 indexes is not simply a function of variation in sample size, and can be interpreted archaeologically.  
182 The RAI of medium big game did, however, show a strong and highly significant correlation with  
183 sample size ( $r_s=0.613$ ,  $p<0.001$ ), probably because the taxa making up this group—ostrich and  
184 boar—occur extremely infrequently in our sample (Total NISP=51). Therefore *mbg* was excluded  
185 from the rest of the analysis.

186

### 187 **Mantel tests and regression**

188

189       Following Stutz and colleagues (Stutz et al., 2009), Mantel tests were used to confirm that  
190 there were statistically significant trends in taxonomic abundance over time. The Mantel test is a  
191 permutation-based (nonparametric) test of the correlation between two matrices of dissimilarity or  
192 distance (Mantel, 1967; Sokal, 1979) and is widely used in ecology and genetics (Legendre and  
193 Fortin, 2010). Essentially, the Mantel test is an extension of conventional measures of correlation,  
194 such as Pearson's  $r$ , Spearman's  $\rho$  or Kendall's  $\tau$ , from comparing two sets of variables directly,  
195 to comparing the pairwise *dissimilarity* between the observations of two sets of variables (which is  
196 mathematically equivalent to comparing *similarity*, its inverse). It has two main advantages over  
197 straightforward correlation tests (Guillot and Rousset, 2013): dissimilarity metrics can summarise  
198 multivariate data for use in a single test (as in this case, where variation in the abundance of multiple  
199 taxonomic groups is combined); and it can be used to detect and account for the correlation of a

200 variable with itself due to proximity of observations (e.g. in space or time), a phenomenon known as  
201 autocorrelation, which otherwise violates the assumption of independence of most parametric  
202 statistical tests. The statistical tests were performed in the R statistical environment (R Core Team,  
203 2016), using the *vegan* package for Mantel tests (Dixon, 2003; Oksanen et al., 2016).

204 Mantel tests were performed to detect temporal autocorrelation in taxonomic composition  
205 data—that is, to test if assemblages that were distantly separated in time also tended to have very  
206 different compositions, and vice versa—which would statistically validate the assumption that  
207 variation in taxonomic abundance is structured by time. First, a matrix of temporal dissimilarity was  
208 computed by calculating the absolute difference between the midpoints of the radiocarbon or  
209 chronotypological age ranges (Table 2) of each possible combination of assemblages. The difference  
210 in taxonomic composition between each of these pairs was summarised using a Morisita–Horn  
211 dissimilarity index (Morisita, 1959; Horn, 1966), which is independent of sample size (Wolda, 1981),  
212 comparing both the NISP of individual taxon and the RAI of our prey type groups. Finally, the  
213 Mantel tests were performed by calculating the Pearson correlation coefficient of these matrices, and  
214 computing a p-value by comparing this result to that of 1000 randomly shuffled permutations of the  
215 same matrices.

216 In the second stage of the analysis, trends in our prey types (excluding *mbg*) were  
217 investigated individually. Two approaches were taken to interrogating the data. In the first, data from  
218 assemblages of the same period were combined, thereby providing a broad view of prey type changes  
219 over time and balancing out the ‘noise’ of variability unrelated to changes through time, e.g.  
220 specialist hunting/trapping locales. In the second approach, the prey type indexes of individual  
221 assemblages were plotted against the median age of the assemblage, to examine trends in more  
222 detail. Because these trends were contained in a single variable and turned out to be relatively linear,  
223 a regression analysis was used to quantify and assess them, rather than further Mantel tests (cf. Stutz

224 et al., 2009). In both cases Stutz et al.'s data from eight Kebaran–Natufian sites in western  
225 Galilee/Mount Carmel were used as a comparison.

226

## 227 **RESULTS**

228 Mantel tests of temporal distance against dissimilarity in taxonomic composition (Morisita–Horn  
229 indexes) revealed a significant correlation, which was substantially stronger when prey type RAIs  
230 were compared ( $r=0.402$ ,  $p=0.00099$ ) rather than individual taxa ( $r=0.191$ ,  $p=0.01898$ ). We drew two  
231 conclusions from these results. First, that significant proportion of the variation in the relative  
232 abundance of taxa can be explained by changes through time; justifying the more detailed  
233 investigation of individual temporal trends carried out in the next stage of our analysis. Second, that  
234 trends in the exploitation of broad prey types are more significant than variation in individual taxa;  
235 validating the use of RAIs.

236

### 237 **Relative prey abundance (RAI) through time**

#### 238 *Large game*

239 Figure 5a shows the relative abundance of large big game (*lgb*) for the eastern Jordan sites to have a  
240 significant, strong correlation with the calendar age of the assemblage ( $r_s=0.500$ ,  $p=0.00307$ ) (note:  
241 E. Jordan *mbg* was not tested due to the above finding that it has inadequate sample size; *mbg*,  
242 however, is shown for western Galilee sites in Figure 5a, where this size category constitutes the  
243 main big game).

244 At the Azraq sites equid and cattle were dominant in assemblages, while in Galilee/Mount  
245 Carmel sites fallow deer are most common. Trends in abundance appear to differ significantly over  
246 time at Azraq Basin sites, with moderate levels of equid/cattle (RAI = c.0.28) from c.28,000 cal BP  
247 (Late Upper Palaeolithic and Initial Epipalaeolithic), an apparent decline in the Early Epipalaeolithic  
248 (c. 20,000 cal BP) but followed by an upward surge (RAI 0.3-0.4) towards 15,000 cal BP. during the

249 Middle and early Late Epipalaeolithic. These changes contrast dramatically with the steady decline  
250 of Galilee/Mount Carmel fallow deer (*mbg*) between 19-13,000 cal BP (ie. Early to Late  
251 Epipalaeolithic (RAI c.0.45 to c.0.07-0.08). A data gap coincident with the Late Natufian and PPNA  
252 obscures the final decline of Azraq cattle/equid, which occurred sometime between 13-10,000 cal BP  
253 (see Yizhaq et al., 2005). Thereafter, c.10-9,000 cal BP (Early to Late PPNB) these large game  
254 animals virtually disappear: they either decline in the vicinity or are not the objects of hunting. It is  
255 interesting to note that in the Galilee/Mount Carmel assemblages, alongside the marked decline of  
256 *mbg* - fallow deer, boar and hartebeest – cattle and equids occurred only in very low proportions  
257 throughout the period examined here.

258  
259 *Small game*  
260 The relative abundance of fast small game shows a significant, strong correlation with the calendar  
261 age of the assemblage ( $r_s=-0.549$ ,  $p=0.00094$ ). However, the relative abundance of slow small game  
262 showed no correlation with calendar age ( $r_s=-0.083$ ,  $p=0.64691$ ), and thus only *fsg* is displayed in  
263 Figure 5b.

264 Fast small game – including fast birds, carnivores and lagomorphs - seem not to have been  
265 important resources in Azraq Basin assemblages until they rise gradually in relative abundance at  
266 c.15,000 cal BP (from the Middle and into the Late Epipalaeolithic). These periods are associated  
267 with climate warming in the post Last Glacial Maximum period, and particularly during the Bølling  
268 Allerød phases. They tend to be marked by increasing abundance of small game, hare, fox and birds,  
269 relative to gazelle. In the Galilee/Mount Carmel assemblages, small game use was insubstantial until  
270 the early Late Epipalaeolithic (c.15,000 cal BP) when the abundance of fast small game increased  
271 dramatically (Figure 5b, following Stutz et al., 2009). Thereafter, the latest Epipalaeolithic/Late  
272 Natufian was marked by a decline in fast small game, and as Stutz and colleagues show,  
273 accompanied by an upward surge in tortoise. From c. 10,900 cal BP (Early and Middle PPNB)

274 Figure 5b shows fast small game reaching high relative abundance levels (RAI >c.0.5) in some  
275 assemblages, before declining at c.9,000 cal BP.

276 It is evident from these analyses that faunal patterns differ greatly between eastern Jordan and  
277 Galilee/Mount Carmel. Summarizing Figures 5 a and b, we see Azraq Basin trends showing  
278 sustained, if not increased, use of large game (cattle and equids) into the Middle and Late  
279 Epipaleolithic, before a complete decline in the PPNB. There is also a slight rise in fast small game  
280 earlier (Middle Epipalaeolithic) than seen in Galilee/Mount Carmel (where it is Late Epipalaeolithic),  
281 but without the high spike. Thereafter high but variable levels of fast small game are seen in the  
282 Azraq Basin Early and Middle PPNB. Acknowledging that Azraq Basin assemblages derive from  
283 varied environmental locations with diverse water and vegetation resources, we next explore whether  
284 these patterns are retained at the individual sites/assemblage level.

285

#### 286 **Site specific relative prey abundance**

287 *Large game* When Azraq Basin assemblages are considered individually (Figure 6, plotted by  
288 archaeological period rather than calendar age), variation in large game abundance is apparent across  
289 the Epipalaeolithic. In the Initial Epipalaeolithic and first stages of the Early Epipalaeolithic large-big  
290 game, mainly equid are relatively common at Uwaynid 18 (RAI c.0.17) sited near to a spring, but  
291 even more abundant at Wadi Jilat 6 Middle (RAI c.0.35) near an at least seasonally well-watered  
292 wadi in the limestone steppe (although note the small sample-size). In the later assemblages of the  
293 Early Epipalaeolithic, however, equid/cattle abundance becomes very low, notably at both of the  
294 large aggregation sites of Wadi Jilat 6 Upper 1-3 levels, and Kharaneh IV (levels B-D). The Middle  
295 Epipalaeolithic sees moderately high but variable equid/cattle abundance at Wadi Jilat 22. A high  
296 peak of large game is seen at Azraq 18, located at the oasis in the centre of the basin. However  
297 during all phases of the PPNB it is evident that cattle/equid were more or less absent from both Wadi

298 Jilat 7 and the site of Dhuweila in the basalt margins. Figure 6 clearly shows the effects of site  
299 location, variation in localized environments, water availability and habitats within the Azraq Basin.  
300

301 *Fast and slow small game* Figure 7 shows patterns for small prey also on an individual  
302 site/assemblage basis. Slow-moving prey, largely tortoise, are uncommon ( $< \text{RAI } 0.05$ ) at most sites  
303 apart from Mid-Late Epipalaeolithic Wadi Jilat 22 (RAI c.0.3) and Mid PPNB Wadi Jilat 32 (c.0.67)  
304 where they appear as a notable presence, but for other PPNB assemblages they have low  
305 representation, and as already established, relative abundance variation over time is not statistically  
306 sound. Fast moving prey were numerous in Wadi Jilat 22, Early and Mid PPNB Wadi Jilat 7 (RAI  
307 max.0.4-0.6) and in Mid PPNB Wadi Jilat 32 where relative numbers peak. These findings contrast  
308 with those from El-Wad Cave and Hayonim Cave where Stutz and colleagues (2009) show small  
309 prey reaching high numbers only in the Late Epipalaeolithic, apparently associated with a decreasing  
310 abundance of gazelle. Tortoises also outnumber fast small prey at Late Epipalaeolithic Hayonim  
311 Terrace and Hilazon Tachtit, but notably never do so at any of the Azraq Basin locations.  
312

313 *Gazelle* The one taxon not elucidated by the above analyses is gazelle - the most common  
314 steppic/desertic mammal in most assemblages - since it serves as a reference index for assessing  
315 variation in other taxa size classes. Figure 8 remedies this by showing how gazelle relative  
316 proportions shift through time, from being the dominant prey throughout the Epipalaeolithic,  
317 appearing in lower relative proportions in the Middle and Late Epipalaeolithic, and being only the  
318 third most common taxon at Late Epipalaeolithic Azraq 18 in the oasis. Gazelle are the major, small-  
319 big game animal but representation is varied in the PPNB, when it is sometimes equalled or exceeded  
320 by hares. Dhuweila in the basalt margins is an exception in showing an assemblage comprising  
321 almost exclusively gazelle.

322 A similar diachronic spectrum through the Epipalaeolithic for Galilee/Mount Carmel faunal  
323 assemblages (Figure 9) shows a more unidirectional trend, with gazelle and fallow deer declining in  
324 the Late Epipalaeolithic, with a corresponding increase in small prey, especially tortoises, partridges  
325 and hare. This picture contrasts with Stiner's (2001) diet breadth study which used assemblages  
326 from more inland Galilee sites (in the Wadi Meged) and found tortoise steadily declining between  
327 c.30,000-10,000 cal. BP. Otherwise, trends were similar. The Azraq Basin picture (e.g. Figure 8)  
328 does show 'directional' trends, but far more fluctuating, perhaps reflecting the larger area and more  
329 varied environmental contexts incorporated in this study (12,000km<sup>2</sup>) compared to that of Stutz et al.,  
330 (2009) (c.3,000km<sup>2</sup>).

331

### 332 **Summary of data patterning**

333 In the Azraq Basin, small game increases within assemblages in the Middle and Late Epipalaeolithic,  
334 at least a millennium earlier than seen in the Galilee/Mount Carmel. But closer inspection shows this  
335 pattern derives from the sequential occupations of one site, Wadi Jilat 22, where high proportions of  
336 bird and tortoise are seen. Fast small game, especially hare, increases sharply within PPNB  
337 assemblages, while tortoise bones remain relatively low in abundance. For large game, Figure 8  
338 shows that cattle did not made a significant contribution to any of the Epipalaeolithic assemblages  
339 except the oasis site Azraq 18 where they dominate; subsequently in the Holocene cattle virtually  
340 disappear. Equid representation is more varied, being at its highest in the Initial Epipalaeolithic,  
341 declining in the Early Epipalaeolithic, increasing again in Middle and Later Epipalaeolithic  
342 assemblages, but becoming rare in the PPNB. How much this patterning reflects climatic shifts in  
343 the Late Pleistocene/early Holocene and attendant ecological changes, or changes in the ways that  
344 hunter-gatherer groups interacted with their prey and impacted wildlife, are explored in the following  
345 section.

346

347 **DISCUSSION**

348 In order to unravel the main influences on the faunal changes documented above, we discuss trends  
349 in the light of three factors: climatic shifts through the time-frame; evidence for hunting pressure on  
350 individual game species; and small game ratios which might reflect site occupation intensity. Our  
351 aim is to examine the combination of climatic and human occupation influences that could have  
352 guided prey choice across the time sequence.

353

354 **Climatic conditions and shifts 30,000 cal BP to 9,000 cal BP**

355 Animal distribution and density in the Azraq Basin – especially for herd ungulates – will have been  
356 influenced by climatic variability, impacting water supply and vegetation, as well as complex factors  
357 relating to soil type, topography and forage. The more regional-scale evidence for climate changes  
358 from the Late Upper Palaeolithic to Late PPNB in the southern Levant is summarized in Table 5,  
359 with data deriving from the Soreq Cave speleothem  $\delta^{13}\text{O}$  and  $\delta^{18}\text{C}$  isotope analyses, and  
360 investigations of Lake Lisan levels (Bar-Matthews, Ayalon and Kaufman, 1997, 1999; Bartov et al.,  
361 2002; Robinson et al., 2006). The right hand columns of Table 5 summarize studies of plant growth  
362 and geomorphology specific to the Azraq Basin (Colledge, Conolly and Shennan, 2004; Jones and  
363 Richter, 2011; Hunt and Garrard, 2013), and it is notable that these eastern Jordan signatures  
364 occasionally deviate from the regional picture.

365 In brief, high stands of Lake Lisan during the cold period preceding and during the early  
366 stages of the Late Glacial Maximum (LGM) have been identified, which are the consequence of  
367 major increases in rainfall coupled with less evaporation associated with the drop in temperature  
368 (Bartov et al., 2002; Hazan et al., 2005; Robinson et al., 2006; Enzel et al., 2008). The cold  
369 conditions of this period featured on both sides of the Jordan Valley rift during the Upper  
370 Palaeolithic and Early Epipaleolithic. Geological sections indicated the presence here of a likely  
371 perennial lake in the Azraq Oasis during this period (Garrard et al., 1988a; Jones and Richter, 2011;

372 Hunt and Garrard, 2013) while sediment profiles at Wadi Jilat 6, Kharaneh IV and Uwaynid 14 and  
373 18, demonstrate that locally available standing water was present at diverse locations through the  
374 LGM and post LGM warming phase prior to the Heinrich 1 event (Hunt and Garrard, 2013; Richter  
375 et al., 2013). This picture of a well-watered landscape was corroborated by archaeobotanical studies  
376 which provide evidence that the broad drainage wadis would have been lined with perennial shrubs,  
377 sedge, grassland and scattered trees (Garrard et al., 1988b; Colledge, 2001). More recently,  
378 geoarchaeological work at Kharaneh IV has confirmed the presence of a relatively lush habitat with  
379 rich vegetation along the adjacent wadi (Maher et al., 2012) while sedimentary successions at Ayn  
380 Qasiyya in the Azraq oasis point to the presence of permanent water and marshland from the Early to  
381 Middle Epipalaeolithic (Richter et al., 2009).

382 Long-term or repeated occupation sites such as Wadi Jilat 6, Ayn Qasiyya and Kharaneh IV  
383 had declined by the end of the post LGM warming phase when water availability may have become  
384 limiting (Bar-Matthews et al., 1999; Robinson et al., 2006; Jones and Richter, 2011; Hunt and  
385 Garrard, 2013). It is notable that Kharaneh IV was established in a late phase of the LGM, and  
386 overlapped with the final phase of occupation of Wadi Jilat 6 which lies 30km to the south. Both  
387 sites are exceptionally large, intensively occupied hunter-gatherer aggregation centres, and have been  
388 called ‘megasites’ (a term more commonly applied to PPN village settlements) and seem  
389 underpinned by an environment of relative lushness (Garrard and Byrd, 1992; Richter et al., 2013).  
390 Both were abandoned during a drier phase following the LGM. In the warm up period following the  
391 Heinrich 1 event there is evidence of localised seasonal marshland in parts of the Wadi Jilat (Hunt  
392 and Garrard, 2013, 74-78) and reoccupation of sites in that area and at Azraq (Wadi Jilat 22, 10 and  
393 8; Azraq 17). Occupation at some of these sites continued into the warmer, moist Bølling Allerød,  
394 however the ensuing cold arid period of the Younger Dryas seems to have led to the disbanding of  
395 communities into small, mobile groups, not easily detected by archaeological survey.

396           There is evidence from other areas of the southern Levant (e.g the Wadi Faynan in south-west  
397 Jordan: Hunt et al., 2004; Finlayson and Mithen, 2007) for moister conditions during the Early  
398 Neolithic, but the environmental (particularly the geological) record from eastern Jordan is more  
399 ambiguous. There is certainly evidence for an expansion of settlement through the PPNB although  
400 the sites appear to have been occupied by seasonally mobile groups (e.g. Wadi Jilat 7, 26 and 32)  
401 (Byrd, 1992; Garrard et al., 1994b; Garrard and Byrd, 2013). There are traces of small-scale  
402 cultivation which may have been opportunistic and limited to seasonally damp alluvial areas or  
403 relating to slightly moister conditions (Colledge, 2001). By c.9000 cal BP Late PPNB sites began to  
404 appear in the Basalt desert fringes at locations such as Dhuweila and Ibn el-Ghazzi (Betts, 1998).

405           Understanding how these local climatic changes through the Late Pleistocene and Early  
406 Holocene may have affected large game availability is clearly complex but we might, for example,  
407 consider differences in water-dependency for the three main taxa: gazelle, equids and cattle. All  
408 Arabian gazelle species (*Gazella subgutturosa*, *G. gazella*, *G. dorcas*) are adaptable grazers and  
409 browsers, independent of standing water, and fairly drought tolerant (Ostrowski, Mésochina and  
410 Williams, 2006), so it is very likely that gazelle herds met both their forage and water requirements  
411 in the Azraq Basin throughout the sequence. Only *G. subgutturosa* has been identified from Azraq  
412 Basin assemblages to date, on the basis of horn-core morphology, from both Early Epipaleolithic and  
413 Neolithic assemblages (e.g. Kharaneh IV, Uwaynid 18, Dhuweila). This steppic species is  
414 independent of standing water, and fairly drought tolerant, so we can assume that fluctuations in  
415 water availability would not have a severe impact on their presence.

416           Equids have different requirements. From the Azraq Basin assemblages, there are hints of  
417 two sizes of equids, probably representing the larger *E. caballus* and smaller *E. hemionus*, with the  
418 latter being identified from dentition at Early Epipalaeolithic Wadi Jilat 6, Late Epipalaeolithic Azraq  
419 18, and Neolithic Dhuweila (Martin, 1994, 1998); the former identified at Ayn Qasiyya (Edwards,  
420 unpublished data), while intense fragmentation renders most postcranial specimens unidentifiable to

421 equid size class. *E hemionus* in particular is characteristic of steppe and desert environments and  
422 finds its forage there. They are both able to obtain their water requirements from vegetation in wet  
423 seasons, but need to drink from standing water every few days in drier seasons (Klingel 1977; Roses  
424 and Moehlman, 2002), and will always stay close to standing water. With this in mind, it is notable  
425 that the fluctuations in the proportions of equids in assemblages (Figure 8) tend to coincide with  
426 wetter and drier phases of the Epipalaeolithic. For example, their consistent presence in the Initial  
427 Epipalaeolithic and early part of the Early Epipalaeolithic marks a time when the Azraq Basin is  
428 evidenced as well-watered. Equids declined in the upper phases of Wadi Jilat 6 and Kharaneh IV  
429 occupation, when water availability seemed to decrease. The Middle Epipalaeolithic witnessed  
430 locally moister conditions and was marked by higher equid proportions in assemblages. Thus  
431 increased equid presence can be linked to the availability of drinking water, although other factors  
432 such as site location and seasonality may also have been causal. It is harder to explain the virtual  
433 disappearance of equids in the PPNB assemblages, if there was increased wetness across the Azraq  
434 Basin. This is explored further below.

435         Turning finally to cattle (*Bos primigenius*), these obligate drinkers require drinking water  
436 every 2-3 days, whether in wet or dry seasons. Wild cattle, and by implication aurochs, have a  
437 strong adherence to standing water, and will not graze further than a day's walk from water sources  
438 and a favoured location would be open areas with grass and marshland around lakes (Garrard, 1980  
439 Table 3B; van Vuure, 2005). It is therefore not surprising that cattle are seen only at Ain Qasiyya  
440 and Azraq 18, both sites within the oasis. While other areas may have had standing water or seasonal  
441 wadis, these did not offer contiguous permanent water sources that allowed wild cattle to thrive.

442         In sum, the effects of the changing climate through the Epipalaeolithic and PPNB in the  
443 Azraq Basin is most likely to have impacted on the presence of equids, since they are occasional  
444 drinkers, being neither independent of standing water (like gazelles), nor obligate drinkers with a  
445 strong adherence to water sources (like cattle). Variation in their relative abundance can be

446 interpreted as environmentally-linked, rather than the result of human impact, at least until the early  
447 Holocene when their disappearance requires further explanation.

448

#### 449 **Evidence for predation pressure**

450 For the Mediterranean vegetation zones of the southern Levant, many authors have argued for  
451 an intensification in gazelle hunting during the Epipalaeolithic. In an important early study, Davis  
452 (1983) found an increase in the proportion of juvenile gazelles within assemblages between the  
453 Mousterian and Natufian which he attributed to year-round hunting pushing down the demographic  
454 profile of gazelle herds. In later broader-scale analyses, Munro also noted increases in juvenile  
455 gazelles between Early/Middle Epipalaeolithic assemblages (Kebaran and Geometric Kebaran)  
456 where juveniles made up less than 30% of gazelles culled, compared to Late Epipalaeolithic  
457 (Natufian) assemblages where they rose above 30% (Munro, 2004). Refining the juvenile fraction  
458 further, Munro (2009) also found that the targeting of ‘fawns’ also increased through the  
459 Epipalaeolithic, even between the early and late Natufian. This was interpreted as Natufian hunters  
460 actively hunting all available gazelle age classes as part of a broader shift in resource intensification  
461 which also included smaller game. This, in turn, was seen as a response to occupation intensity and  
462 resource stress, ultimately driven by population pressure (see Stiner, Munro and Surovell, 2000;  
463 Stiner and Munro, 2002; Munro, 2009; Stutz, Munro and Bar-Oz, 2009). While there are other  
464 factors that play into an ‘increase’ in juvenile animals observed in assemblages - such as site  
465 seasonality and variability in hunting strategies (see Simmons and Ilany, 1975-77 and Davis, 1983  
466 for excellent considerations of these factors) - there is wide acceptance in southern Levantine  
467 prehistory that predation pressure on gazelles is reflected in the demography of cull profiles.

468 With this in mind we might predict for the Azraq Basin that an increase in the proportion of  
469 juvenile gazelles, alongside evidence for targeting fawns, indicates hunting pressure. This prediction  
470 is considered in the following section. It should be noted that Munro’s (2004) threshold of 30%

471 juveniles stems only from internal observation of her study site data. One of us (Martin, 2000, 25,  
472 Table 12) found, in a review of modern single-birthing gazelle populations, records of juveniles  
473 making up 39% of herds in normal years under no conditions of hunting pressure. In our  
474 examination of gazelle cull data below, we therefore use this higher figure (39%) as a threshold  
475 below which we do not assume pressure on gazelle herds.

476 From the Azraq Basin assemblages, there is sufficient epiphyseal fusion data for an  
477 examination of gazelle cull profiles, while only brief comment can be made concerning the sparse  
478 equids data and there are insufficient data to address hunting pressure on cattle.

479

#### 480 *Gazelle*

481 Table 6 shows gazelle fusion data from selected Azraq Basin assemblages (the number of elements  
482 with fusion data is shown in the right hand column; note some are too small to be reliable). The left  
483 column shows the number of indeterminate longbones of gazelle size which are of neonate size  
484 (assumed to be gazelle, since there is no similar sized ungulate present). Data are also given for the  
485 percentage of unfused elements that fuse between birth and 7 months, those that fuse between 3 and  
486 7 months, and those that fuse by c18 months (following Munro, Bar-Oz and Stutz, 2009). Unless  
487 otherwise noted, we assume a spring birth peak for gazelles in the Azraq Basin (Martin, 2000, 19-  
488 20).

489 Early Epipalaeolithic assemblages in the limestone steppe, e.g. Kharaneh IV and Wadi Jilat 6,  
490 show overall juvenile cull percentages of 25-35%, which lie well within the range of single birthing  
491 gazelle populations in most Middle Eastern and indeed east African habitats (Martin, 2000, 25-6,  
492 Table 12). There are also low numbers of very young animals/neonates represented in these  
493 assemblages, particularly animals of less than 7 months old (represented by unfused proximal radii  
494 and phalanges, distal humeri and scapula glenoid). These large-scale repeated occupations therefore  
495 do not show any evidence for hunting pressure, despite clearly having a strong focus on gazelle

496 hunting. The data rather seem to show sustainable hunting practices, which did not target newborn  
497 calves, or females in late gestation period, or even a particularly high proportion of juveniles and  
498 sub-adults.

499         A different picture is seen at Early Epipalaeolithic Ayn Qasiyya at the centre of the drainage  
500 basin, which has far higher juvenile proportions (48% and 39% respectively for A and B, Edwards,  
501 unpublished data). These proportions are equal to or above the expectations of representative  
502 hunting of single-birthing gazelle populations and various explanations should be considered: 1)  
503 hunting pressure, driving up the proportions of juveniles; 2) double-birthing of gazelle in the lush  
504 oasis environment; 3) selective hunting of juvenile animals.

505         As noted above, the expectation for hunting pressure is that alongside high juvenile counts,  
506 the killing of younger classes of fawns should also be seen, as evidence of all age-classes being  
507 targeted. At Ain Qasiyya there are very few remains of calves up to 7 months. Could this be due to  
508 wet/marshy burial environments potentially degrading and selectively eliminating young unfused  
509 bone (see Gordon and Buikstra, 1981; Mays, 2010, for human bone)? This possibility cannot be  
510 dismissed, but considering that other Azraq Basin sites in wetlands and marsh environments include  
511 sometimes high numbers of these very young age classes (Table 6, WJ22 Mid, AZ18) it is difficult to  
512 argue that Ain Qasiyya alone suffered taphonomic loss of this age-class of bone. Rather, it is  
513 parsimonious to assume that bones of gazelle fawns were not present at Ain Qasiyya in perceptible  
514 numbers.

515         The possibility of gazelle herds ‘double birthing’ in the wetter oasis locale also needs  
516 consideration, since it would result in the presence of higher relative proportions of juvenile animals  
517 to adults. While *Gazella subgutturosa* normally give birth once a year (Martin, 2000), they can birth  
518 twice a year in environments with permanent water, food and shade, where the lack of seasonal stress  
519 can produce two fawning periods (Habibi, 1991; Kingswood and Blank, 1996; Dunham, 1997), one  
520 in spring and another in autumn. A current programme of gazelle dental isotope analyses will inform

521 on animal birth seasons in future. Until then, there is no firm evidence to support or dismiss the idea.  
522 If gazelle were double-birthing, there would be higher proportions of juvenile animals in the  
523 environment during each season (see Baharav, 1983; Martin, 2000, 26) and certainly far higher than  
524 a 39% expectation. In such a scenario there would be no need to invoke hunting pressure arguments  
525 to explain 'high' proportions of juveniles in cull patterns.

526         Regardless of the possibility of double-birthing, Table 6 shows that the 'high' proportions of  
527 juvenile gazelle deaths at Ain Qasiyya do not include fawns under the age of c.7 months. The  
528 avoidance of fawns might well be expected in a hunting practice where nursery herds, including  
529 young animals with their mothers, are not the target of hunts but left to grow larger in body size (or  
530 to reproduce in the case of mothers). There is therefore some evidence for selective avoidance of  
531 animal groups during hunting, whether intentional or not, while there is with no direct evidence for  
532 hunting pressure at Ain Qasiyya.

533         At Middle Epipalaeolithic Wadi Jilat 22, both levels show overall juvenile counts (at 7-18  
534 months) in the 30% range (32% and 36%), higher than seen at earlier sites in the limestone steppe  
535 (Table 6), but still within expectations of 'representative' culling scenarios of single birthing  
536 populations. There are, however, increased numbers of fawns culled within the first 7 months of life  
537 and notable lower percentages of gazelles hunted overall at Wadi Jilat 22 (Figure 8). While the  
538 expectations for hunting pressure are not met, the high fawn count needs consideration. We have  
539 argued elsewhere (Martin, Edwards and Garrard, 2013) that Wadi Jilat 22 is a seasonal hunting  
540 locale in a wetland setting, focused on trapping birds of prey - particularly eagles - while on their  
541 spring or autumn passage. The presence of newborn gazelles indicates a spring or early summer  
542 occupation, and the targeting of nursery herds, or inexperienced young game around the local marsh  
543 seems best explained as an opportunistic strategy while waiting for birds of prey. Wadi Jilat 22  
544 occupations are likely to have been highly seasonally restricted, and considering the specialised  
545 nature of the site (Garrard and Byrd, 1992, 2013) where gazelle hunting was not the main focus of

546 activity, the gazelle cull evidence seems to reflect seasonality, rather than human pressure on  
547 wildlife. Late Epipalaeolithic Azraq 18 has a very small sample of gazelle fusion data and is not  
548 discussed further.

549 Early and Middle PPNB occupations at the seasonal village of Wadi Jilat 7 see relatively high  
550 culling of fawns up to 7 months old, and a higher overall juvenile cull (40 and 42% respectively),  
551 where gazelle proportions are again low and hare exploitation high (Figure 8). Spring occupation is  
552 likely, and since Colledge (2001) has reported small-scale experimentation with crop planting at this  
553 site, residence may have extended into late spring/early summer for harvesting (Garrard et al., 1996).  
554 The evidence for culling fawns perhaps reflects the targeting of nursery herds, while hunters seem to  
555 have been equally engaged in trapping local small game, predominantly hare, as gazelle hunting  
556 (Figure 8). Within this more human-impacted 'anthropogenic' environment, gazelle cull patterns  
557 provide good evidence for pressure on herds, with hunting hitting young age classes. Whether this  
558 reflects more widespread steppic pressure on game animals is difficult to gauge since PPNB sites and  
559 assemblages in the steppe are sparse. The stone-built structural footings characteristic of steppe sites  
560 in this period - for example the upright limestone slab foundations which may have had  
561 brush/hide/cloth roofs at Wadi Jilat 7, 26, 32 (Baird et al., 1992; Garrard et al., 1994b) - attest to  
562 repeated seasonal visits. Sites are very different from large permanently occupied PPNB village  
563 settlements seen in the Mediterranean zone to the west. It is hard to imagine small seasonally mobile  
564 steppe groups impacting game herds on a wide-scale in this period, but the faunal patterns from WJ7  
565 do suggest local pressure on game, where herds may have been deterred from the immediate vicinity  
566 of settlements and there is evidence of indiscriminate culling of young gazelles.

567 Late PPNB Dhuweila in the basalt desert shows a significant cull of animals in each of the  
568 young and sub-adult age classes, with an overall very high proportion of juveniles in the assemblage  
569 (55%), seemingly indicative of indiscriminate hunting. The assemblage includes over 90% gazelle,  
570 with evidence for intensive carcass processing (Martin, 1998). Dhuweila is a short-term, repeatedly

571 visited, seasonal hunting camp (Betts, 1998) situated on a highpoint, overlooking seasonally flooded  
572 mud flats, and appears to have been a dedicated gazelle hunting camp. Betts (1998) suggested that  
573 the Late PPNB phase of the site was built into a long basalt guide-wall, perhaps part of a kite  
574 (hunting structure), and while this is not unanimously accepted (Zeder, 2012), it is easy to imagine  
575 hunters preparing trackways or guiding walls to divert gazelle herds in their direction. The  
576 demographic profile evidence showing the culling of large numbers of fawns, alongside an overall  
577 55% juveniles, which exceeds all expectations for single-birthing herds (see Martin, 2000 Table 12),  
578 and meets expectations for hunting pressure. The data indicate that hunting in this locale was  
579 impacting the demographic profile of gazelle herds in the Late PPNB.

580         In sum, throughout the Early Epipalaeolithic, hunter-gatherers seemed to practice sustainable  
581 exploitation of gazelle as their main prey, with no apparent hunting pressure. We also find no  
582 evidence of gazelle hunting pressure in Middle Epipalaeolithic assemblages, where lower gazelle  
583 proportions and cull patterns are best explained in other ways. It is only in the Early and Middle  
584 PPNB in the limestone steppe that there is clear evidence for some human impact on gazelle herds.  
585 We propose some displacement of gazelle herds, maybe only seasonally, an effect that likely  
586 increased with the later Neolithic introduction of domestic caprines to the steppe (Garrard, Colledge  
587 and Martin, 1996; Martin, 1999). Significant hunting pressure on gazelles is first witnessed at Late  
588 PPNB Dhuweila; whether this was achieved with hunting traps or guide-walls will no doubt continue  
589 to be debated (Helms and Betts, 1987) but there is clear evidence of intensive hunting.

590         While we argue above for intensive gazelle hunting by the Late PPNB, there is no evidence  
591 for the decimation of herds. The repeated later Neolithic occupations at Dhuweila, for example,  
592 continue to show intensive gazelle hunting (>90% of assemblages), indicating large numbers of  
593 animals were present in the basalt desert during this period. While hunting methods exerted pressure  
594 on herds, they did not, as some have previously suggested (Legge and Rowley-Conwy 1987; 2000)  
595 drive gazelle to extinction in prehistory in the Jordan steppes/deserts.

596  
597 *Equids*  
598 Equids are the second most common large game animals in the Azraq Basin after gazelle, and as  
599 suggested above may have been subject to changing environmental pressures, particularly  
600 fluctuations in water availability. This could explain variations in their representation in the  
601 limestone steppe and at the central oasis, and through wetter and drier phases of the Epipalaeolithic.  
602 Was hunting pressure also a factor affecting equid numbers at the end of the Pleistocene and into the  
603 early Holocene? Assessment of pressure on equids is complicated by our poor understanding of the  
604 species represented at sites, which are often not identifiable beyond genus level due to high  
605 fragmentation of bones and teeth. In the Levant, particularly in late Pleistocene/early Holocene  
606 steppe-grasslands, we might expect the presence of smaller equids including the now extinct Syrian  
607 wild ass (*Equus hemionus hemippus*) or the Persian onager (*E. hemionus onager*). The wild horse  
608 (*E. caballus ferus*) is also likely to have been present and possibly the wild ass (*E. africanus*) whose  
609 distribution ranged from north African into the Levant in the early Holocene (Uerpmann, 1987).  
610 Another possible resident equid was the European wild ass (*Equus hydruntinus*). Some reservation  
611 concerning identification is necessary since aDNA work shows that hemiones and hydruntines share  
612 similar genomes. Comparisons of mitochondrial DNA show the same 28-29 base pair deletion which  
613 might indicate that they are not true separate species (Orlando et al., 2006, 2009). In addition the  
614 DNA hypervariable regions (Geigl and Grange, 2012) demonstrate that hydruntines and hemiones  
615 are closely linked, but comparisons of grouped haplotype sequences find a significant genetic  
616 distance that points to distinct speciation, although it is impossible currently to be confident that they  
617 are different species. For now, we question our prior identification of hydruntines in the Azraq Basin  
618 (e.g. Azraq 18: Garrard, 1991; Martin, 1994).

619           For our study sites equid dentition has allowed identification of hemiones at Wadi Jilat 6  
620 (Upper), Ayn Qasiyya, Azraq 18 and Dhuweila Late PPNB, while identification of sub-species has

621 not been possible. Hemionus would be well adapted to the steppe grasslands, semi-desert and desert  
622 plains of the Azraq Basin. Recent studies of *E. hemionus* in central Asia and reintroduced  
623 populations in the southern Levant show they graze in lush seasons turning to browse in drier  
624 seasons. Males hold territories throughout the year with females entering them during the mating  
625 season (Klingel, 1977; Reading et al., 2001; Rubenstein et al., 2007). The less frequent presence of  
626 wild horse is also attested from a single tooth at Ayn Qasiyya (Edwards, unpublished data).  
627 The decline of equids in the Azraq Basin during the Holocene needs consideration since *E. hemionus*  
628 in particular should have found sufficient forage and water. In the Neolithic, equids are present at  
629 Late PPNB Dhuweila (see Table 4) and the Later Neolithic phase at Dhuweila (Martin, 1998 Table  
630 8.2, 161-2); they also appear at later prehistoric sites in the Burqu' area (Betts et al., 2013) but  
631 always in low numbers. Their low proportions are curious since onagers are known from historical  
632 periods to be common steppe inhabitants, and Syrian wild asses found refuge into the 20<sup>th</sup> century in  
633 areas of the Azraq Basin (Harper, 1945; Nelson, 1973, 160), only to be driven to extinction by  
634 regular hunting with firearms.

635         Small sample sizes render it impossible to assess hunting pressure on equids (Table 7), and  
636 fusion data show only that both adults and juveniles were present throughout the Epipalaeolithic with  
637 no equivalent data for Neolithic assemblages. While there is therefore no direct evidence for hunting  
638 pressure, we suggest that a combination of fluctuating water availability alongside continued hunting  
639 of equids impacted their presence in the Azraq Basin. Furthermore, Neolithic occupations, while still  
640 seasonal in nature, showed more investment in built structures and were located closer to bodies of  
641 water (e.g. wadi beds, lake edges) than in the Epipalaeolithic. Such factors may have displaced  
642 water-adhering wild asses and interfered with their territories and habitat use, as documented in  
643 recent times in Iran where equid populations were depressed by encroaching human settlement (Tatin  
644 et al., 2003). Loss of habitat due to human landscape interference, grazing livestock, and

645 competition for water and forage is listed among the major threats to *E. hemionus* by the IUCN Red  
646 List (<http://www.iucnredlist.org/details/7951/0>).

647

#### 648 **Small game ratios and site occupation intensity**

649 Turing to small game animals, Stiner and colleagues (2000, 2002) have proposed that within the  
650 overall diet breadth of an assemblage, examination of the small game fraction can indicate levels of  
651 site occupation intensity. Following optimal foraging theory predictions, they have demonstrated that  
652 hunter-gatherer-collectors would take easy-to-catch slow-moving prey in preference to harder-to-  
653 catch fast-moving prey, and that a decline in slow-moving prey accompanied by an increase in fast-  
654 moving prey indicated an exhaustion of the former. Stiner and Munro (2002) see the prime reason  
655 for this as over-exploitation of food resources in the immediate environment, resulting from intensive  
656 site occupation through multiple seasons, or year-round. Application of this logic to southern  
657 Levantine faunal assemblages found that tortoises constituted the major slow-moving prey, while  
658 hares and birds made up the fast-moving fraction.

659         For Azraq Basin assemblages, Figure 10 shows the relative proportions of tortoise, hare and  
660 birds *within* the small game category. The overall percentage of the small-game fraction is given  
661 below the assemblage labels on the x-axis. It should be noted that raptors are excluded from the  
662 ‘bird’ counts, since these analyses focus on animals as food choices, and raptors are most probably  
663 captured for non-food purposes. We also stress that tortoise sample sizes are sometimes very small,  
664 but note that our quantification method for tortoise remains (see Table 4 caption) already divides  
665 scutes by 60, to standardize with mammalian/bird anatomy (unlike some zooarchaeologists), thus  
666 NISP counts would be far higher. Figure 10 shows that during the Early Epipalaeolithic the  
667 percentage of small-game in assemblages was relatively low, always <10% and often far less. Large  
668 game always make up most of the diet, especially if considering animal size and weight. Hare  
669 generally outnumber tortoise, which are nevertheless always present, and bird representation is

670 highly variable. There are no strong trends: for example successive phases of occupation at  
671 Kharaneh IV do not see a decline in tortoise representation, which would have indicated exhaustion  
672 of small slow game in this environment. The ratio of tortoise:hare instead seems remarkably  
673 constant at Kharaneh IV showing consistent practices and perhaps underlying resource availability.

674 From the Middle Epipalaeolithic onwards, assemblages generally show far higher overall  
675 proportions of small game (with the exception of Dhuweila) ranging from 16-65%. The Middle  
676 Epipalaeolithic pattern, however, is different to that seen in the PPNB: at Wadi Jilat 22, tortoises far  
677 outnumber hare and birds, with no decline in tortoise remains between the middle and upper phases  
678 of the site which might be expected if hunters over-impacted local animal resources. This pattern  
679 shows no evidence of intense site occupation; slow-moving tortoises do not become depleted.

680 PPNB assemblages in the same location (e.g. Wadi Jilat 7) show a very different pattern.  
681 Small game counts overall are even higher than in the Middle Epipalaeolithic, with tortoise  
682 proportions low and hare consistently outnumbering tortoises four/five-fold. We have referred  
683 above to the different nature of occupation during the PPNB in the steppe, with stone-built structures  
684 and evidence for multiple subsistence activities with small-scale cultivation, in addition to hunting  
685 and trapping. Animal procurement activities here favoured hare capture above tortoise use; the  
686 various reasons for this will be discussed below, but one plausible explanation is that the more  
687 intensive nature of these PPNB occupations impacted on the slow-moving and very slow-  
688 reproducing tortoises, while hare populations proved more resilient (Stiner et al., 2002).

689

## 690 **Conclusions**

691 This study has examined patterns of wild game exploitation at hunter gatherer sites in the Azraq  
692 Basin of eastern Jordan, following approaches described by Stutz, Munro and Bar-Oz (2009) in  
693 exploration of faunal assemblage change in the Galilee/Mount Carmel area. Stutz and colleagues  
694 showed a steady decline in large game from the Early Epipalaeolithic to the Late Natufian,

695 accompanied by an increase in small game in the Natufian, interpreted as reflecting demographically  
696 driven resource pressure. Their results support earlier proposals (Munro, 2004, 2009a; Stiner, 2001:  
697 Stiner et al., 1999) that increased use of small game, particularly resilient fast small game in the  
698 Early and Late Natufian, reflects a decline of large game due to over-hunting, associated with  
699 increasing site occupation intensity and ultimately driven by population pressure.

700 Statistically robust diachronic trends for the Azraq Basin across a longer timeframe from the  
701 Upper Palaeolithic to the Late PPNB differ from those seen in the Galilee/Mount Carmel area. For  
702 example, equids (the main large game in the steppic Azraq Basin) increase in relative abundance in  
703 the Middle and Late Epipalaeolithic (at Wadi Jilat 22 and Azraq 18) after low representation in the  
704 Early Epipalaeolithic, a fluctuation that convincingly reflects changing water availability rather than  
705 human impact. From the PPNB onwards, however, the very low equid representation in assemblages  
706 is counter to expectations based on increased moisture/water availability (Table 5). While we cannot  
707 rule out the possibility that steppic PPNB hunters had a socio-cultural focus on gazelle hunting rather  
708 than equids, we argue above that PPNB settlement types generated an increased local  
709 ‘anthropogenic’ impact, and this together with continued hunting would have placed pressure on  
710 herds and seasonally and spatially displaced them, sending them into decline. This does not equate  
711 to long-term extinction or extirpation, however, since wild equids had a continued presence in the  
712 area until recent times.

713 Wild cattle had a clear adherence to the central oasis of the Azraq Basin. Assemblages  
714 analysed from this area are limited to the Epipalaeolithic, so we currently cannot gauge pressures on  
715 cattle into the Holocene. However, their high representation at Late Epipalaeolithic Azraq 18,  
716 alongside equids, demonstrates that large game thrived locally into the Terminal Pleistocene, a very  
717 different scenario to that in the Galilee/Mount Carmel area where Stutz and colleagues (2009) find a  
718 diminished large game category by the late Natufian.

719 Turning to small game, the slight ‘increase’ of small fast game observed at Middle  
720 Epipalaeolithic Wadi Jilat 22 cautions against superficial interpretation of temporal trends without  
721 paying due attention to the specifics of site function. Middle Epipalaeolithic Wadi Jilat 22 sees a  
722 high representation of birds which, as we have argued elsewhere, represents specialized seasonal  
723 trapping, providing non-food items such as feathers and talons for onward exchange (Martin,  
724 Edwards and Garrard, 2013). This cultural practice was made possible by the development of local  
725 seasonal marshland in Wadi Jilat which attended climatic warming (see Table 5). It seems quite  
726 different from the small-game increases seen in the Middle to Late Epipalaeolithic of the  
727 Mediterranean zone which are interpreted as being food animals.

728 It is not until the PPNB that the impacts of a more anthropogenic footprint are seen in the  
729 form of small game increases in Wadi Jilat assemblages. Wadi Jilat 7 shows a faunal signature  
730 consistent with more intensive occupation: here high proportions of small game reflect the  
731 displacement, loss of territory and perhaps overhunting of equids, and high hare:tortoise ratios  
732 suggest the over-harvesting of the latter, although we note small assemblage sample sizes. While the  
733 Wadi Jilat 7 structures are small-scale and seasonal (Baird et al., 1992; Garrard et al., 1994b), lengths  
734 of stay are likely to have been influenced not only by animal life, but also by small-scale cultivation  
735 of crops. The observed decrease in gazelle at PPNB Wadi Jilat 7 and the hunting of gazelle fawns  
736 and calves, hints at range fragmentation and pressure on resources, which are supplemented with  
737 small animal trapping and crop cultivation. Our zooarchaeological evidence argues that these  
738 observations represent the earliest evidence of increased pressure on resources detected in Azraq  
739 Basin environments. Until this point, hunter-gatherer groups seem to have ‘trodden lightly’ in the  
740 steppe (a phrase borrowed from Munro et al., 2015).

741 This is a localized picture however, since the eastern edge of the Azraq Basin supports  
742 gazelle herds in abundance during this period at Late PPNB Dhuweila (seen also in the Late  
743 Neolithic) (Betts, 1998; Martin, 1998). The apparently indiscriminate hunting tactics of killing

744 newborns, fawns and juveniles at Dhuweila, impacted the demographic make-up of gazelle  
745 populations and reflects a focused targeting of a single species. By this period, mixed agriculture and  
746 livestock herding were well-established at village sites in the fertile areas of the southern Levant,  
747 with trading and exchange networks well-attested (Bar-Yosef and Belfer-Cohen, 1989; Richter et al.,  
748 2011). This raises the possibility that the intensive gazelle hunting observed at Dhuweila could have  
749 been a part of a regional network for meat or hide exchange, rather than simply catering for local  
750 hunter-gatherer needs.

751         While witnessed a few thousand years later, the changes seen in the Wadi Jilat PPNB sites  
752 mirror to some extent those seen in the Late Epipalaeolithic in the southern Levantine Mediterranean  
753 zones, where small game replace larger game (Stiner et al., 1999, 2000; Stiner, 2001; Stiner and  
754 Munro, 2002), while noting the Azraq Basin Late Epipalaeolithic-PPNA data-gap. However, for the  
755 Azraq Basin PPNB, demographic pressure arguments do not seem relevant: the Wadi Jilat PPNB  
756 sites are relatively small, seasonal and not consistent with large populations. As argued above, these  
757 factors may have deterred/disrupted the range used by larger game and encouraged trapping of local  
758 smaller game. The Wadi Jilat PPNB sites equally do not fit Zeder's scenario for diversified prey in  
759 which she sees hunter-gatherers moving into resource rich environments with multiple eco-zones,  
760 where a wide range of large and small game could be hunted and trapped (Zeder, 2012). A note of  
761 caution must be raised when using bone assemblages to trace faunal turnover: it is well-understood  
762 that assemblages do not necessarily reflect animal communities living around sites, neither in  
763 taxonomic range nor proportion, since they are filtered through human selection. Some Azraq Basin  
764 faunal assemblages reveal social preferences or avoidance of particular animals, such as the highly  
765 selective raptor trapping at Wadi Jilat 22 or gazelle hunting at Dhuweila. Also, at Ain Qasiyya at the  
766 oasis edge, a higher representation of cattle might be expected, but assemblages are dominated by  
767 gazelle, hinting at cattle avoidance. Understanding site functions and activities, in addition to

768 environmental contexts and hunting and trapping patterns, is essential prior to interpretation of  
769 diachronic faunal shifts.

770 Finally, comparisons made in this paper between the eastern Jordan Azraq Basin and western  
771 Galilee/Mount Carmel sites draw attention to significant differences between both their  
772 environmental settings and archaeological settlement patterns. Azraq Basin sites are all in open-air  
773 locations, ranging from hilly limestone steppes to the west, to marshland and springs in the central  
774 oasis, and basaltic hills to the east (see Figure 2). Scattered trees, perennial shrubs and grassland  
775 would have been features of the Early and Middle Epipalaeolithic landscape with rich vegetation  
776 alongside wadis and in marshland areas. The post-Younger Dryas warming in the Holocene saw  
777 restoration of springs and marshes (Garrard et al., 1988b; Colledge, 2001; Maher et al., 2012) but  
778 throughout the periods under discussion in this study, it is likely that only seasonal occupation could  
779 be sustained.

780 By contrast, the western Galilee/Mount Carmel sites were located across more verdant,  
781 fertile locations with plentiful open woodland in the hilly Mount Carmel area and open grasslands on  
782 the plain between the hills and the sea (Saxon, Martin and Bar-Yosef, 1978; Kaufman, 1987; Bar-Oz,  
783 Dayan and Kaufman, 1999; Stutz et al., 2009). The faunal trends observed here between the  
784 Geometric Kebaran and Natufian (e.g. Munro, 2009) of intensification of gazelle exploitation, and  
785 the replacement of large game hunting with the collection of tortoises, and trapping of hare and game  
786 birds, are concurrent with apparent human population growth, and increasingly permanently-  
787 occupied aggregated settlements in the area (Bar-Yosef, 2000; Munro, 2004). Large Natufian sites  
788 are interpreted as permanent basecamps (Bar-Yosef and Belfer-Cohen, 1989, 1991) which would  
789 have placed very different pressures on local wildlife to seasonal habitations.

790 Contrasting patterns of wildlife exploitation seen in the Azraq Basin can, at least in part, be  
791 explained by the very different environmental setting and nature of human occupation seen through  
792 these periods. The Azraq Basin case-study presented here thus cautions against universal broad-scale

793 explanations of hunting pressure and faunal change, even within relatively small regions such as the  
794 southern Levant. We have demonstrated much variation even between the micro-environments of  
795 the Azraq Basin itself, so variation is to be expected across the region in general. This study reveals  
796 diverse hunter-gatherer use of the wildlife through time and across the different locales examined,  
797 but what emerges is that human impacts on steppe and desert fauna through the Epipalaeolithic and  
798 PPNB seem both local and in many cases short-term, unlike the large-game suppressed situations  
799 reported from west of the Rift Valley. Resource pressures leading to game over-kill, whether  
800 population-driven or otherwise, are not currently apparent east of the Jordan River (Edwards and  
801 Martin, 2013; Munro et al., 2015).

802

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813

1 **References**

- 2 Baharav, D., 1983. Reproductive strategies in female Mountain and Dorcas gazelles (*Gazella gazella*  
3 *gazella* and *Gazella dorcas*). *Journal of Zoology* 200, 445-453.  
4
- 5 Baird, D., Garrard, A., Martin, L., Wright, K., 1992. Prehistoric environment and settlement in the  
6 Azraq Basin: An interim report on the 1989 excavation season. *Levant* 24, 1-31.  
7
- 8 Bar-Matthews, M., Ayalon, A., Kaufman, A., 1997. Late Quaternary paleoclimate in the eastern  
9 Mediterranean region from stable isotope analysis of speleothems at Soreq Cave, Israel. *Quaternary*  
10 *Research* 47, 155–168.  
11
- 12 Bar-Matthews, M., Ayalon, A., Kaufman A., Wasserburg, G., 1999. The Eastern Mediterranean  
13 paleoclimate as a reflection of regional events: Soreq cave, Israel. *Earth and Planetary Science*  
14 *Letters* 166, 85-95.  
15
- 16 Bar-Oz G. N., Dayan T., Kaufman D., 1999. The Epipalaeolithic Faunal Sequence in Israel: A View  
17 from Neve David. *Journal of Archaeological Science* 26, 67–82.  
18
- 19 Bar-Yosef, O., Belfer-Cohen, A. 1989. The origins of sedentism and farming communities in the  
20 Levant. *Journal of World Prehistory* 3, 447-98.  
21
- 22 Bartov, Y., Stein, M., Enzel, Y., Agnon, A., Reches, Z., 2002. Lake levels and sequence stratigraphy  
23 of Lake Lisan, the late Pleistocene precursor of the Dead Sea. *Quaternary Research* 57, 9–21.  
24
- 25 Belfer-Cohen A., 1991. The Natufian in the Levant. *Annual Review of Anthropology* 20, 167-186.  
26
- 27 Betts, A. V. G., 1985. Black Desert Survey, Jordan. Third preliminary report. *Levant* 17, 29-52.  
28
- 29 Betts, A. V. G., 1986. The Prehistory of the Basalt Desert Transjordan: An Analysis. Unpublished  
30 PhD thesis. Institute of Archaeology, University of London.  
31
- 32 Betts, A. V. G., 1988. Excavations at Dhuweila, Eastern Jordan. A Preliminary Report. *Annual of*  
33 *the Department of Antiquities of Jordan* 33, 212-228.  
34
- 35 Betts, A. V. G., 1991. The Late Epipalaeolithic in the Black Desert, eastern Jordan. In: Bar-Yosef, O.  
36 & Valla, F. (Eds.), *The Natufian Culture in the Levant. International Monographs in Prehistory, Ann*  
37 *Arbor*, pp. 217–34.
- 38 Betts, A. V. G., 1998. The Harra and the Hamad: Excavations and Explorations in Eastern Jordan,  
39 Volume 1. *Sheffield Archaeological Monographs* 9, Sheffield Academic Press, Sheffield.
- 40 Betts, A. V. G., Cropper, D., Martin, L., McCartney, C., 2013. The Later Prehistory of the Badia.  
41 *Excavations and Surveys in Eastern Jordan. Levant Supplementary Series* 11, Oxbow, Oxford.
- 42 Byrd, B. F., 1988. Late Pleistocene settlement diversity in the Azraq Basin. *Paléorient* 14, 257-264.  
43
- 44 Byrd, B. F., 1992. The dispersal of food production across the Levant. In: Price, T. D (Ed.),  
45 *Transitions to Agriculture in Prehistory. Prehistory Press, Madison*, pp. 49-61.  
46

- 47 Byrd, B. F., 2005. Reassessing the emergence of village life in the Near East. *Journal of*  
48 *Archaeological Research* 13, 231-290.
- 49
- 50 Byrd, B. F., Garrard, A., 1990. The last glacial maximum in the Jordanian desert. In Gamble, C.,  
51 Soffer, O. (Eds.), *The World at 18,000 BP. Volume 2, Low Latitudes*. Unwin and Hyman, London,  
52 pp. 78-96.
- 53
- 54 Byrd, B. F., Garrard, A. N., Brandy, P., 2015. Modelling foraging ranges and spatial organisation of  
55 Late Pleistocene hunter-gatherers in the southern Levant – A least-cost GIS approach. *Quaternary*  
56 *International*; <http://dx.doi.org/10.1016/j.quaint.2015.07.048>.
- 57 Cleveland, W.S., Devlin, S.J., 1988. Locally Weighted Regression: An Approach to Regression  
58 Analysis by Local Fitting. *J. Am. Stat. Assoc.* 83, 596–610.
- 59
- 60 Colledge, S., 2001. *Plant Exploitation on Epipalaeolithic and Early Neolithic Sites in the Levant*.  
61 *BAR International Series 986, British Archaeological Reports*, Oxford.
- 62
- 63 Colledge, S., Conolly, J., Shennan, S., 2004. Archaeobotanical evidence for the spread of farming in  
64 the eastern Mediterranean. *Current Anthropology* 45, 35-58.
- 65
- 66 Copeland, L. and Hours, F., 1989. *The Hammer on the Rock. Studies in the Early Palaeolithic of*  
67 *Azraq, Jordan. BAR International Series 540, British Archaeological Reports*, Oxford.
- 68
- 69 Davis, S., 1983. The age profiles of Gazelle predated by ancient man in Israel: Possible evidence for  
70 a shift from seasonality to sedentism in the Natufian. *Paléorient* 9, 55-63.
- 71
- 72 Davis, S., 1985. A preliminary report on the fauna from Hatoula: A Natufian Khiamian (PPNA) site  
73 near Latroun, Israel, p71-98 in *Le Site Natoufien-Khiamien de Hatoula* (Eds. Lechevallier M, Ronen  
74 A.). *Centre de Recherche Français de Jérusalem*.
- 75
- 76 Dixon, P., 2003. VEGAN, a package of R functions for community ecology. *J. Veg. Sci.* 14, 927–  
77 930.
- 78
- 79 Dunham, K. M., 1997. Population growth of mountain gazelles reintroduced in central Arabia.  
80 *Biological Conservation* 81, 205–214.
- 81
- 82 Edwards, P. C., 1989. Problems of recognizing earliest sedentism: the Natufian example. *Journal of*  
83 *Mediterranean Archaeology* 2, 5-48.
- 84
- 85 Edwards, P. C., Bocquentin, F., Colledge, S., Edwards, Y.H., Le Dosseur, G., Martin, L., Zvonkica,  
86 S., Webb, J., 2013. Wadi Hammeh 27: an open-air ‘base-camp’ on the fringe of the Natufian  
87 ‘homeland’. In: Bar-Yosef, O., Valla, F. (Eds.), *Natufian Foragers in the Levant. Terminal*  
88 *Pleistocene Social Changes in Western Asia. International Monographs in Prehistory*, Ann Arbor, pp.  
89 319-348.
- 90
- 91 Edwards Y. H., Martin, L., 2013. Animal bones and archaeozoological analysis. In Edwards, P. C.  
92 (Ed.) *Wadi Hammeh 27, an Early Natufian Settlement at Pella in Jordan*. Brill, Leiden, pp. 321-350.
- 93

- 94 Enzel, Y., Amit, R., Dayan, U., Crouvi, O., Kahana, R., Ziv, B., Sharon, D., 2008. The climatic and  
95 physiographic controls of the eastern Mediterranean over the late Pleistocene climates in the southern  
96 Levant and its neighbouring deserts. *Global and Planetary Change* 60, 165–192.  
97
- 98 Finlayson, W., Mithen, S. (Eds.), 2007. *The Early Prehistory of Wadi Faynan, Southern Jordan: Archaeological Survey of Wadis Faynan, Ghuwayr and Al Bustan and Evaluation of the Pre-Pottery Neolithic A Site of WF16*. Levant Supplementary Series 4, Oxbow, Oxford.  
99  
100  
101
- 102 France, R. L., 2010. *Restorative Development of Devastated Ecocultural Landscapes*. CRC Press,  
103 Boca Raton.  
104
- 105 Garrard, A. N., 1980. *Man-animal-plant relationships during the Upper Pleistocene and Early Holocene of the Levant*. Unpublished PhD thesis, University of Cambridge.  
106  
107
- 108 Garrard, A. N., 1991. Natufian settlement in the Azraq Basin, eastern Jordan. In Bar-Yosef, O., Valla, F. (Eds.), *The Natufian Culture in the Levant*. International Monographs in Prehistory. Ann Arbor, pp. 235-244.  
109  
110  
111
- 112 Garrard, A. N., 1998. Environment and cultural adaptations in the Azraq Basin: 24,000-7,000 BP. In Henry, D. O. (Ed.), *The Prehistoric Archaeology of Jordan*. BAR International Series 705. British Archaeological Report, Oxford, pp. 139-148.  
113  
114  
115
- 116 Garrard, A., Baird, D., Byrd, B., 1994a. The chronological basis and significance of the Late Palaeolithic and Neolithic sequence in the Azraq Basin, Jordan. In Bar-Yosef, O., Kra, R. (Eds.), *Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean*. Radiocarbon. University Arizona, Tuscon, pp. 177-199.  
117  
118  
119  
120
- 121 Garrard, A., Baird, D., Colledge, S., Martin, L., Wright, K., 1994b. Prehistoric environment and settlement in the Azraq basin: an interim report on the 1987 and 1988 excavations seasons. *Levant* 26, 73-109.  
122  
123  
124
- 125 Garrard, A., Betts, A., Byrd, B., Hunt, C., 1988a. Summary of palaeoenvironmental and prehistoric investigations in the Azraq Basin. In Garrard, A. N., Gebel H.G. (Eds.), *The Prehistory of Jordan*. BAR International Series 396, British Archaeological Reports, Oxford, pp. 311-337.  
126  
127  
128
- 129 Garrard, A. N., Byrd, B. F., 1992. New dimensions to the Epipalaeolithic of the Wadi el-Jilat in central Jordan. *Paléorient* 18/1, 47-62.  
130  
131
- 132 Garrard, A. N., Byrd, B. F., 2013. *Beyond the Fertile Crescent. Late Palaeolithic and Neolithic Communities of the Jordanian steppe. The Azraq Basin Project, Volume I. Project Background and the Late Palaeolithic (Geological Context and Technology)*. Levant Supplementary Series 13, Oxbow, Oxford.  
133  
134  
135  
136
- 137 Garrard, A., Colledge, S., Hunt, C. and Montague, R., 1988. Environment and subsistence during the late Pleistocene and early Holocene in the Azraq Basin. *Paléorient*, 14/2, 40-49.  
138  
139
- 140 Garrard, A., Colledge, S., Martin, L., 1996. The emergence of crop cultivation and caprine herding in the “Marginal Zone” of the southern Levant. In Harris, D. R. (Ed.) *The Origins and Spread of Agriculture and Pastoralism in Eurasia*. University College London, London, pp. 204-226.  
141  
142  
143

144 Geigl E-M., Grange T., 2012. Eurasian wild asses in time and space: Morphological versus genetic  
145 diversity. *Annals of Anatomy* 194, 88-102.  
146  
147 Goring-Morris, A. N., Belfer-Cohen, A., 1998. The articulation of cultural processes and late  
148 Quaternary environmental changes in CisJordan. *Paléorient* 23, 71-93.  
149  
150 Grayson D.K., 1984. *Quantitative Zooarchaeology*. Academic Press. New York.  
151  
152 Guillot, G., Rousset, F., 2013. Dismantling the Mantel tests. *Methods Ecol. Evol.* 4, 336–344.  
153  
154 Habibi, K., 1991. Reproductive strategy of the Farasan gazelle (*Gazella gazella farasani*). *Journal of*  
155 *Arid Environments* 23, 351–353.  
156  
157 Harper, F., 1945. *Extinct and vanishing mammals of the Old World*. Special Public. 12. American  
158 Committee for International Wild Life Protection, New York, NY.  
159  
160 Hazan N., Stein M., Agnon A., Marco S., Nadel D., Negendanke, J., Schwab M., Neev D., 2005. The  
161 late Quaternary limnological history of Lake Kinneret (Sea of Galilee), Israel. *Quaternary Research*  
162 63, 60–77.  
163  
164 Henry, D. O., 1989. *From Foraging to Agriculture. The Levant at the End of the Ice Age*. University  
165 of Pennsylvania Press, Philadelphia.  
166  
167 Horn, H.S., 1966. Measurement of “overlap” in comparative ecological studies. *Am. Nat.* 419–424.  
168  
169 Hunt, C., Elrishi, H., Gilbertson, D., Grattan, J., McLaren, S., Pyatt, F., Rushworth, G., Barker, G.,  
170 2004. Early Holocene environments in the Wadi Faynan, Jordan. *The Holocene* 14, 921-930.  
171  
172 Hunt, C.O., Garrard, A.N., 2013. Section B: The Late Palaeolithic – Geological Context. In Garrard,  
173 A. N., Byrd, B. F. (Eds) *Beyond the Fertile Crescent: Late Palaeolithic and Neolithic Communities*  
174 *of the Jordanian Steppe. The Azraq Basin Project, Volume 1: Project Background and the Late*  
175 *Palaeolithic (Geological Context and Technology)*. Levant Supplementary Series 13. Oxford:  
176 Oxbow, pp. 53-135.  
177  
178 Jones, M., Richter, T., 2011. Paleoclimatic and archaeological implications of Pleistocene and  
179 Holocene environments in Azraq, Jordan. *Quaternary Research* 76, 363–372.  
180  
181 Kaufman D. 1987. Excavations at the Geometric Kebaran Site of Neve David, Israel: a preliminary  
182 report. *Quartär* 26: 53-72.  
183  
184 Kingswood, S., Blank, D., 1996. *Gazella subgutturosa*. *Mammalian Species* 518, 1-10. Accessed  
185 April 01, 2009  
186  
187 Klingel H., 1977. Observations on Social Organization and Behaviour of African and Asiatic Wild  
188 Asses (*Equus africanus* and *E. hemionus*). *Zeitschrift für Tierpsychologie* 44, 323–331.  
189  
190 Legendre, P., Fortin, M.-J., 2010. Comparison of the Mantel test and alternative approaches for  
191 detecting complex multivariate relationships in the spatial analysis of genetic data. *Mol. Ecol.*  
192 *Resour.* 10, 831–844.  
193

- 194  
195 Legge, A. J., Rowley-Conwy, P. A., 1987. Gazelle killing in Stone Age Syria. *Scientific American*  
196 255, 88-95.  
197
- 198 Legge, A. J., Rowley-Conwy, P. A., 2000. The Exploitation of Animals. p 423-474 In *Village on*  
199 *the Euphrates: from foraging to farming at Abu Hureyra* (Eds: Moore A., Hillman G. and Legge A.).  
200 Oxford University Press.  
201
- 202 Maher, L. A., Richter, T., Macdonald, D., Jones, M. D., Martin, L., Stock, J. T., 2012. Twenty  
203 thousand-year-old huts at a hunter-gatherer settlement in eastern Jordan. *PLoS ONE* 7 (2) e31447.  
204 doi:10.1371/journal.pone.0031447.  
205
- 206 Mantel, N., 1967. The detection of disease clustering and a generalized regression approach. *Cancer*  
207 *Res.* 27, 209–220.  
208
- 209 Martin, L., 1994. Hunting and herding in a semiarid region. Faunal remains from the Epipalaeolithic  
210 and Neolithic of the eastern Jordanian Steppe. Unpublished PhD dissertation, University of Sheffield.
- 211 Martin, L., 1998. The Animal Bones. In Betts, A. V. (Ed.) *The Harra and the Hamad: Excavations*  
212 *and Surveys in Eastern Jordan*, volume 1. Sheffield Archaeological Monographs 9, Sheffield  
213 Academic Press, Sheffield, pp. 159-184.
- 214 Martin, L., 1999. Mammal remains from the eastern Jordanian Neolithic, and the nature of caprine  
215 herding in the steppe. *Paléorient* 25/2, 87-104.  
216
- 217 Martin, L., 2000. Gazelle (*Gazella sp*) behavioural ecology: predicting animal behaviour for  
218 prehistoric environments in south-west Asia. *Journal of Zoology (London)* 250, 13-30.  
219
- 220 Martin, L., Edwards, Y. H., Garrard, A., 2010. Hunting practises at an eastern Jordan Epipaleolithic  
221 aggregation site: the case of Kharaneh IV. *Levant* 42, 107-135.  
222
- 223 Martin, L., Edwards, Y. H., Garrard, A., 2013. Broad spectrum or specialized activity? Birds and  
224 tortoises at the Epipalaeolithic site of Wadi Jilat 22 in the eastern Jordan steppe. *Antiquity* 87, 649-  
225 665.  
226
- 227 Morisita, M., 1959. Measuring of interspecific association and similarity between communities.  
228 *Mem. Fac. Sci. Kyushu Univ. Series E* 3, 65–80.  
229
- 230 Muheisen, M., 1988. The Epipalaeolithic phases of Kharaneh IV. In Garrard, A. N., Gebel, H.-G.  
231 (Eds.) *The Prehistory of Jordan*. BAR International Series 396, British Archaeological Reports,  
232 Oxford, pp. 353-367.  
233
- 234 Muheisen, M., Wada, H., 1995. An analysis of the microliths at Kharaneh IV Phase D, Square  
235 A20/37. *Paléorient* 21/1, 75-95.  
236
- 237 Munro, N. D., 2003. Small game, the Younger Dryas and the transition to agriculture in the southern  
238 Levant. *Mitteilungen der Gesellschaft Für Urgeschichte* 12, 47-71.  
239
- 240 Munro, N. D., 2004. Hunting pressure and occupation intensity in the Natufian. *Current*  
241 *Anthropology* 45 (Supplement), S5-S33.

242  
243 Munro, N. D., 2009. Epipalaeolithic subsistence intensification in the southern Levant: the faunal  
244 evidence. In Hublin J-J., Richards M.J. (Eds.), Integrating Approaches to the studies of Palaeolithic  
245 Subsistence. Springer, Netherlands, pp. 141-155.  
246  
247 Munro, N. D., Bar-Oz, G., Stutz, A., 2009. Aging mountain gazelle (*Gazella gazella*): refining  
248 methods of tooth eruption and wear and bone fusion. *Journal of Archaeological Science* 36, 752-  
249 763.  
250  
251 Munro N.D., Kennerty M., Meier J.S., Samei S., al-Nahar M., Olszewski D. I., 2015. Human hunting  
252 and site occupation intensity in the Early Epipaleolithic of the Jordanian western highlands.  
253 *Quaternary International* 1-9.  
254  
255 Nelson, B., 1973. Azraq Desert Oasis. Allen Lane, London.  
256  
257 Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O’Hara, R.B., Simpson, G.L.,  
258 Solymos, P., Stevens, M.H.H., Wagner, H., 2016. vegan: Community Ecology Package.  
259 <https://CRAN.R-project.org/package=vegan>  
260  
261 Orlando, L., Mashkour, M., Burke, A., Douady, C. J., Eisenmann, V., Hanni, C., 2006. Geographic  
262 distribution of an extinct equid (*Equus hydruntinus*:Mammalia, Equidae) revealed by morphological  
263 and genetical analyses of fossils. *Molecular Ecology* 15:2083–2093.  
264  
265 Orlando, L., Metcalf, J., Alberdi, M., Telles-Antunes, M., Bonjean, D., et al, 2009. Revising the  
266 recent evolutionary history of equids using ancient DNA. *PNAS* 106, 21754-21759.  
267  
268 Ostrowski S., Mesochina P., Williams J. B., 2006. Physiological adjustments of sand gazelles  
269 (*Gazella subgutturosa*) to a boom-or-bust economy: standard fasting metabolic rate, total evaporative  
270 water loss, and changes in the sizes of organs during food and water restriction. *Physiological and*  
271 *Biochemical Zoology* 79, 810-9.  
272  
273 R Core Team, 2016. R: A Language and Environment for Statistical Computing. R Foundation for  
274 Statistical Computing, Vienna, Austria.  
275  
276 Reading, R., Richard, P., Mix, H. M., Lhagvasuren, B., Feh, C., Kane, D. P., Dulmasteren, S.,  
277 Enkhbold, S., 2001. Status and distribution of khulan (*Equus hemionus*). *Mongolia Journal of*  
278 *Zoology* 254, 381–389.  
279  
280 Richter, T., Allcock, S., Jones, M., Maher, L., Martin, L., Stock, J., Thorne, B., 2009. New light on  
281 final Pleistocene settlement diversity in the Azraq Basin (Jordan): Recent excavations at Ayn  
282 Qasiyya. *Paléorient* 35, 49-68.  
283  
284 Richter, T., Arranz, A., House, M., Rafaiah, A. M., Yeomans, L., 2014. Preliminary report on the  
285 second season of excavations at Shubayqa 1. *Neo-Lithics* 1/14, 3-10.  
286  
287 Richter, T., Garrard, A., Allcock, S., Maher, L., 2011. Interaction before agriculture: exchanging  
288 material and sharing knowledge in the Final Pleistocene Levant. *Cambridge Archaeological Journal*  
21, 95-114.

- 289 Richter, T., Maher, L., Garrard, A., Edinborough, K., Jones, M. D., Stock, J. T. 2013. Epipalaeolithic  
290 settlement dynamics in southwest Asia: new radiocarbon evidence from the Azraq Basin. *Journal of*  
291 *Quaternary Science* 28: 467-479.
- 292
- 293 Robinson, S. A., Black, S., Sellwood, B. W., Valdes, P. J., 2006. A review of palaeoclimates and  
294 palaeoenvironments in the Levant and Eastern Mediterranean from 25,000 to 5000 years BP: setting  
295 the environmental background for the evolution of human civilisation. *Quaternary Science Reviews*  
296 25, 1517–1541.
- 297
- 298 Rollefson, G. O., Quintero, L., Wilke, P., 2001. Azraq Wetand Survey 2000. Preliminary Report.  
299 *Annual of the Department of Antiquities of Jordan* 45, 71-82.
- 300
- 301 Roses Moehlman, P., 2002. Equids: Zebras, Asses and Horses Status survey and Conservation  
302 Action Plan. IUCN/SSC Equid Specialist Group. IUCN World Conservation Union 2002.
- 303
- 304 Rubenstein, D.I., Sundaesan, S., Fischhoff, I., Saltz, D., 2007. Social Networks in Wild Asses:  
305 Comparing Patterns and Processes among Populations. *Erforsch Biol Ress Mongolei* 10, 159-176
- 306
- 307 Saxon, E. C., Martin, G., Bar-Yosef, O., 1978. An open-air site on the Israeli littoral. *Paléorient*  
308 4:253-266
- 309
- 310 Silver, I.A. 1969. The ageing of domestic animals. In D.R. Brothwell and E.S. Higgs (Eds) *Science*  
311 *in Archaeology: A Survey of Progress and Research*, 283-302. London: Thames and Hudson.
- 312
- 313 Simmons A.H., Ilany G., 1975-1977. What mean These Bones? *Paléorient* 3, 269-274.
- 314
- 315 Sokal, R.R., 1979. Testing Statistical Significance of Geographic Variation Patterns. *Syst. Zool.* 28,  
316 227–232.
- 317
- 318 Stiner, M. C., 2001. Thirty years on: the “Broad Spectrum Revolution” and Palaeolithic demography.  
319 *Proceedings of the National Academy of Sciences USA* 98, 6993-6996.
- 320
- 321 Stiner, M., Munro, N., 2002. Approaches to prehistoric diet breadth, demography and prey ranking  
322 systems in time and space. *Journal of Archaeological Method and Theory* 9, 181-214.
- 323
- 324 Stiner, M., Munro, N., Surovell, T., 2000. The tortoise and the hare; Small-game use, the Broad-  
325 Spectrum Revolution and Palaeolithic demography. *Current Anthropology* 41, 39-73.
- 326
- 327 Stiner, M. C., Munro, N. D., Surovell, T. A., Tchernov, E., Bar-Yosef, O., 1999. Palaeolithic  
328 population growth pulses evidenced by small animal exploitation. *Science* 283, 190-194.
- 329
- 330 Stutz, A. J., Munro, N., Bar-Oz, G., 2009. Increasing the resolution of the Broad Spectrum  
331 Revolution in the southern Levantine Epipaleolithic (19–12 ka). *Journal of Human Evolution* 56,  
332 294–306.
- 333
- 334 Tatin, L., Bijan, F., Darreh-Shoori, T., Tourenq, C., Tatin, D., Azmayesh, B., 2003. The last  
335 populations of the critically endangered onager *Equus hemionus onager* in Iran: Urgent requirements  
336 for protection and study. *Oryx* 37, 4.
- 337

- 338 Tchernov, E., 1991. Biological evidence for human sedentism in south-west Asia during the  
339 Natufian. In Bar-Yosef, O., Valla, F. (Eds.), *The Natufian Culture in the Levant*. International  
340 Monographs in Prehistory, Ann Arbor, pp. 315-340.  
341
- 342 Tchernov, E., 1994. The fauna of Netiv Hagdud: a summary. In Bar-Yosef, O., Gopher, A. (Eds.) *An  
343 Early Neolithic Village in the Jordan Valley. Part 1: The Archaeology of Netiv Hagdud*. American  
344 School of Prehistory Bulletin 43. Peabody Museum of Archaeology and Ethnography, Harvard, pp.  
345 237-245.  
346
- 347 Uerpmann, H-P., 1987. *The Ancient Distribution of Ungulate Mammals in the Middle East*. Ludwig  
348 Reichert Verlag, Wiesbaden.  
349
- 350 van Vuure T., 2005. *Retracing the aurochs: history, morphology and ecology of an extinct wild ox*.  
351 Pensoft: Sofia.  
352
- 353 Wolda, H., 1981. Similarity indices, sample size and diversity. *Oecologia* 50, 296–302.
- 354 Yizhaq M., Mintz G., Cohen I., Khalaily H., Weine S., Boarett E., 2005. Quality controlled  
355 radiocarbon dating of bones and charcoal from the early Pre-Pottery Neolithic B (PPNB) of Motza  
356 (Israel). *Radiocarbon* 47, 193–206.  
357
- 358 Zeder, M. A., 2012. The Broad Spectrum Revolution at 40: Resource diversity, intensification, and  
359 an alternative to optimal foraging explanations. *Journal of Anthropological Archaeology* 31, 241–  
360 264.  
361

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### Tables

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## Figures

1. Map of northern Jordan and adjacent areas, showing location of sites referred to in text. 1: Wadi Jilat; 2: Kharaneh IV; 3: Uwaynid; 4: Azraq and Ayn Qasiyya; 5: Khallat Anaza; 6: Dhuweila; 7: Ibn el Ghazzi, 8: Hefzibah and Nahal Hadera V, 9: el-Wad. 10: Neve David. 11: Hayonim. 12: Hilazon Tachtit. The map also shows the boundary of the Azraq Basin, the basaltic areas, and current annual rainfall.
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assemblage code. Note small prey values range from 1.5% at Dhuweila (Dhw) to 64.9% at Wadi Jilat 7-4 (WJ7 4) and 97.5% at Wadi Jilat 32 (WJ32).

Table

Period	Site name & code	Approx site area m <sup>2</sup>	Excav area m <sup>2</sup>	m asl	Region	Local position & proximity to water sources	Site reference	Fauna reference
LPPNB	Ibn el-Ghazzi	c.1050	c.36	695	basalt desert to east of Azraq	hilltop overlooking wadis & mudflats	Betts 1985	Martin 1994; 1999
LPPNB	Dhuweila (Dhw)	c. 700	c.240	635	basalt desert to east of Azraq	rocky rising ground overlooking wadis & mudflats	Betts 1998 (p37-50)	Martin 1994; 1998; 1999
EPPNB-LPPNB	Wadi Jilat 7 (WJ7)	2,250	77	785	limestone and flint hills in steppe/ desert transition zone	terrace adjacent to Wadi Jilat gorge; seasonally water filled	Garrard et al.1994b	Martin 1994; 1999
MPPNB	Wadi Jilat 26 (WJ26)	7,850	164.5	785	limestone and flint hills in steppe/ desert transition zone	terrace adjacent to Wadi Jilat gorge; seasonally water filled	Garrard et al 1994b	Martin 1994; 1999
MPPNB	Wadi Jilat 32 (WJ32)	2000	5	810	limestone and flint hills in steppe/ desert transition zone	hillside above Wadi Jilat	Baird et al 1992	Martin 1994; 1999
Late EpiPal	Khallat Anaza	2,000	12	c.1200	basalt region	lower slopes Jebel Druze; basalt out-crop above Wadi Rajil near winter plunge pools	Betts 1998	Martin 1994
Late EpiPal	Azraq 18 (Az18)	1,400	6	508	central Azraq basin	close to major springs & playa.	Garrard 1991; Garrard & Byrd 2013	Martin 1994
Mid-early Late EpiPal	Wadi Jilat 8 (WJ8)	6,300	4	775	limestone and flint hills in steppe/ desert transition zone	terrace above Wadi Jilat gorge	Garrard & Byrd 2013	Martin 1994
Mid & early Late EpiPal	Wadi Jilat 22 (WJ22)	3,500	4	770	limestone and flint hills in steppe/ desert transition zone	terrace above Wadi Jilat gorge.	Garrard & Byrd 1992; Garrard & Byrd 2013	Martin 1994; Martin, Edwards & Garrard 2013
Early-Mid EpiPal	Wadi Jilat 10 (WJ10)	c.450	8	805	limestone and flint hills in steppe/ desert transition zone	terrace above Wadi Jilat gorge	Garrard & Byrd 2013	Martin 1994
Early EpiPal	Kharaneh IV (KHIV)	21,500	16	640	wide valley set between limestone, chalk and flint hills	lower terrace of Wadi al Kharaneh draining eastward to Azraq basin; double mound	Muheisen 1988; Muheisen & Wada 1995; Maher et al. 2012	Martin, Edwards & Garrard 2010
Early EpiPal	Ayn Qasiyya (AQ)	c.2,500	77	c.500	central Azraq oasis	close to major springs	Richter et al 2009	Edwards (unpublished data]
late Up Pal-Early EpiPal	Wadi Jilat 6 (WJ6)	19,175	4	790	limestone and flint hills in steppe/ desert transition zone	terrace above Wadi Jilat gorge; large double mound.	Garrard & Byrd 1992; Garrard & Byrd 2013	Martin 1994; Martin, Edwards & Garrard 2010
Late Up Pal-Initial EpiPal	Uwaynid 18 (UW18)	875	10	525	alluvial plain at margins of basalt outlier and limestone/marls	terrace close to ancient spring & near to confluence of several wadis	Garrard & Byrd 2013	Martin 1994
Late Up Pal	Wadi Jilat 9 (WJ9)	6,750	8	810	limestone and flint hills in steppe/ desert transition zone	terrace above Wadi Jilat gorge	Garrard & Byrd 2013	Martin 1994
Late Up Pal-Mid EpiPal	Azraq 17 (AZ17)	3,100	15	508	central Azraq basin	island in marshland close to springs.	Garrard & Byrd 2013	Martin 1994

Table 1

Table 2

<b>Period</b>	<b>Site/assemblage</b>	<b>ka cal BP radiocarbon</b>	<b>Chronotypology based on lithics</b>
Late PPNB	Ibn el-Ghazzi Dhw WJ7 5	9.5-9.1	9.5-8.9 9.5-8.9
Mid PPNB	WJ26 WJ32 WJ7 2 WJ7 3 WJ7 4	9.9-9.5 10.2-9.3	10.4-9.5
E PPNB	WJ7 1		10.9-10.4
Late EpiPal	KhAnz AZ18		13-12.0 14.0-13.0
early Late EpiPal	WJ22 Up	14.0-13.6	
Mid-Early Late EpiPal	WJ8	16.0-15.5	
Mid EpiPal	WJ22 Mid WJ22 Low	15.7-14.9 16.3-15.8	
Early EpiPal- Mid EpiPal	WJ10 T2	18.5-14.3	
Early EpiPal	KHIV D KHIV C AQ D KHIV B KHIV A WJ6 Up AZ17 T1 AQ B AQ A WJ6 Mid	19.0-18.7 19.4-19.1 19.3-18.9 19.5-19.2 20-18.7 20.2-19.9 23.8-20.5	20.0-18.7 21.3-19.7
Initial EpiPal	WJ6 Low UW 18 T2 Up	24.1-22.8	24.0-21.3
Late Upper Pal	WJ9 T1/2 AZ17 T2 UW18 T2 Low	25.9-24.8 28.2-27.8	

Table 3

Period	Occupation	
	short term	repeated or longer term
Late PPNB		Ibn el-Ghazzi** Dhw** WJ7 5
Mid PPNB		WJ26 WJ32 WJ7 2 WJ7 3 WJ7 4
E PPNB		WJ7 1
Late Epi Pal		KhAnz*** AZ18
Early Late Epi Pal		WJ22 Up
Mid- Early Late Epi Pal		WJ8
Mid Epi Pal Mid Epi Pal	WJ22 Low	WJ22 Mid
Early EpiPal- Mid EpiPal	WJ10 T2	
Early EpiPal	KHIV C*, ^ AQ D^^  AZ17 T1  WJ6 Mid^	KHIV D*  KHIV B* KHIV A* WJ6 Up  AQ B^^ AQ A^^
Initial EpiPal	WJ6 Low^	UW 18 T2 Up
Late Upper Pal	AZ17 T2 UW18 T2 Low	WJ9 T1/2



Sites	Years cal BP	Climate phase	Soreq Cave speleothems <sup>2</sup>	Lake Lisan levels <sup>1,3</sup>	Plant growth	Eastern Jordan geomorphology
Dhw	8,000		8 -7.7ky - increased rainfall		Dhw: wild einkorn & barley; grasses; chenopods e.g. stipa and saltbush <sup>7</sup>	
WJ7 5	9000		sudden cold event & decreased rain			AQ springs reestablished <sup>5</sup>
WJ26, WJ7 2-4	10,000	Holocene	short warmer spells	level stabilises c.400mbsl <sup>1,8,3</sup>	WJ7: domestic emmer; wild & domestic einkorn & barley, grasses, pistachio, lentils & other taxa <sup>7</sup>	warmer conditions: AQ channel fill; floods <sup>5</sup>
	11,000					
	12,000	Younger Dryas	sea surface temperature drop c. 13.2-11.4 ky - cold period	lowering lake levels >410mbsl; rainfall < 150mm per annum at W. Faynan <sup>3,8</sup>	Levant chenopods & artemesia high <sup>3</sup>	AQ drying of springs; arid period <sup>5</sup>
	13,000	Bolling Allerød		increased precipitation/evaporation ratio <sup>3</sup>		
AZ18	14,000		c.14ky - warmest period		Med' area increased C3 plants <sup>2</sup>	sand deposit, more arid enviro AZ18, WJ22 <sup>4</sup>
WJ22 Up				lake levels high <sup>1</sup>		WJ22 marshland disappears <sup>4</sup>
WJ8						
WJ22 Mid	15,000	Pre-Bolling warming				sandy aeolian sedimentation WJ10 <sup>4</sup> extended annual flooding; <i>Phragmites</i> indicating seasonal marsh WJ22 <sup>4</sup>
WJ22 Low: WJ10T2	16,000	Heinrich 1 Event	c.19-14.5ky - gradual temperature increase with short cooler period	lowering lake levels: reduction in evaporation & precipitation <sup>3</sup>		
	17,000	post LGM warming start	c.16.5kyr			reduction in water availability reduced lake levels at Azraq Oases
	18,000		increased temperature & rainfall	major fall in lake levels <sup>1,8</sup>		abandonment mega-sites <sup>5,6</sup>
KHIV D	19,000		coldest & driest conditions		WJ6 upper level: steppic shrubs, sedge indicates nearby water <sup>7</sup>	increasing aridity at WJ6 <sup>6,7</sup> AQ 'cool marsh' <sup>6</sup>
KHIV B		Late Glacial Maximum	rain fall 200-400mm; Eastern Med dust transport high		Med' area C3 & increasing C4 plants <sup>2</sup>	
AZ17 T1: WJ6Up:KHIVA	20,000					
AQ B	21,000			23 -19ky small rise in lake levels <sup>4</sup>		reduced water but marsh develops at AQ <sup>5</sup> evaporation low; year round water in wadis; freshwater snails at KHIV <sup>6</sup> WJ6 & UW18 some loess deposition <sup>7</sup>
WJ6 Mid	22,000					
AQ A	23,000					
	23,000	Heinrich 2 Event	extreme cooling	sharp lowering lake levels; reduced evaporation <sup>1,3</sup>		WJ6 palaeosol formation & UW18 marsh <sup>4</sup>
UW 18 T2 Up: WJ6 Low	25,000		very cold /dry	Lake Lisan & Kinneret merge <sup>~</sup>	Med' area C3 and C4 plants mixed <sup>~</sup>	WJ9 more arid & aeolian sedimentation <sup>~</sup>
WJ9 T1/2	28,000					
UW18 T2 Low				27-26 lake levels significant rise <sup>4,3</sup>		

Table 5

Table 6

period	site	neonate (n)	% Unfused				
			px rad/px phal 1 0-7 months	dist hum/scap 3-7 months	dist tibia 7-18 months	other 7-18 months	total N with fusion info
LPPNB	DH 1	0	23	19	43	55	745
MPPNB	WJ7 2-4	0	14	11	39	42	147
EPPNB	WJ7 1	0	22	0	0	40	27
LEP	AZ18	0	0	50	0	38	15
ELEP	WJ22 Up	2	0	20	25	36	107
MEP	WJ22 Mid	11	10	10	40	32	41
EEP	KHIV D	4	1	1	27	34	1673
EEP	KHIV C	0	0	0	25	35	73
EEP	KHIV B	6	1	0	12	27	456
EEP	KH1V A	8	1	1	28	25	508
EEP	WJ6A	1	1	0	29	32	402
EEP	AQ B	0	1	1	31	39	559
EEP	AQ A	not recorded	2	0	14	48	105
Int EEP	WJ6B	0	0	0	0	14	19
Int EEP	UW18	0	0	0	0	33	80

Abbreviations: px = proximal; dist = distal; rad = radius; phal = phalanx; hum = humerus; scap = scapula.

Table 7.

equid fusion period	site	px ph1 & ph2 >c.15 months			hum dist/ rad px/ mp dist 15-18 months			pelv & tib distal 18-24 months			hum px/rad d/ulna, femur, tib px/calc 36-42 months			equid NISP %
		F	UF	%F	F	UF	%F	F	UF	%F	F	UF	%F	
		LEP	AZ18	2.5	0.5	83.3	2	0	100	0	1	0	2	
ELEP	WJ22 Up	1.5	1	60	0	0	0	1	0	100	3	0	100	13
MEP	WJ22 Mid	1.5	0	100	6	0	100	0	0	0	1	1	50	1
EEP	WJ6 Up	7	0.5fg	93.3	3	0	100	3	1fg	75	2	6	25	14
EEP	AQ A/B	1	0	100	0	0	0	1	1	50	2	1	66.6	11
EEP	WJ6 Mid	1.5	1.5	50	0	0	0	0	1	0	0	0	0	32
IntEP	UW18Tr2Up	9	0	100	0	0	0	0	0	0	0	0	0	14

Abbreviations: px = proximal; ph1 = phalanx 1; ph2 = phalanx 2; dist (d) = distal; hum = humerus; rad = radius; mp = metapodial; pelv = pelvis; tib = tibia; cal = calcaneum

Figure  
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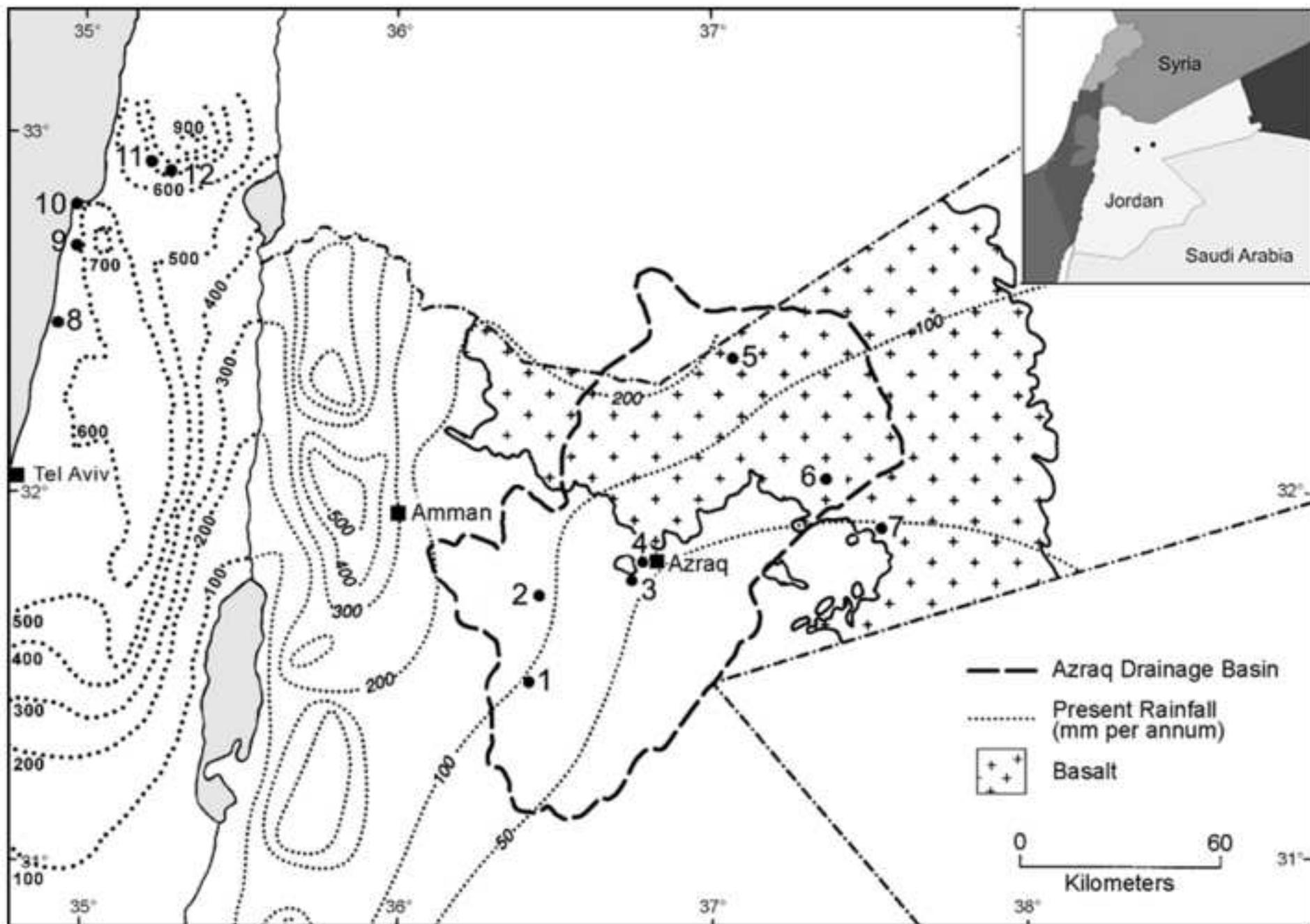
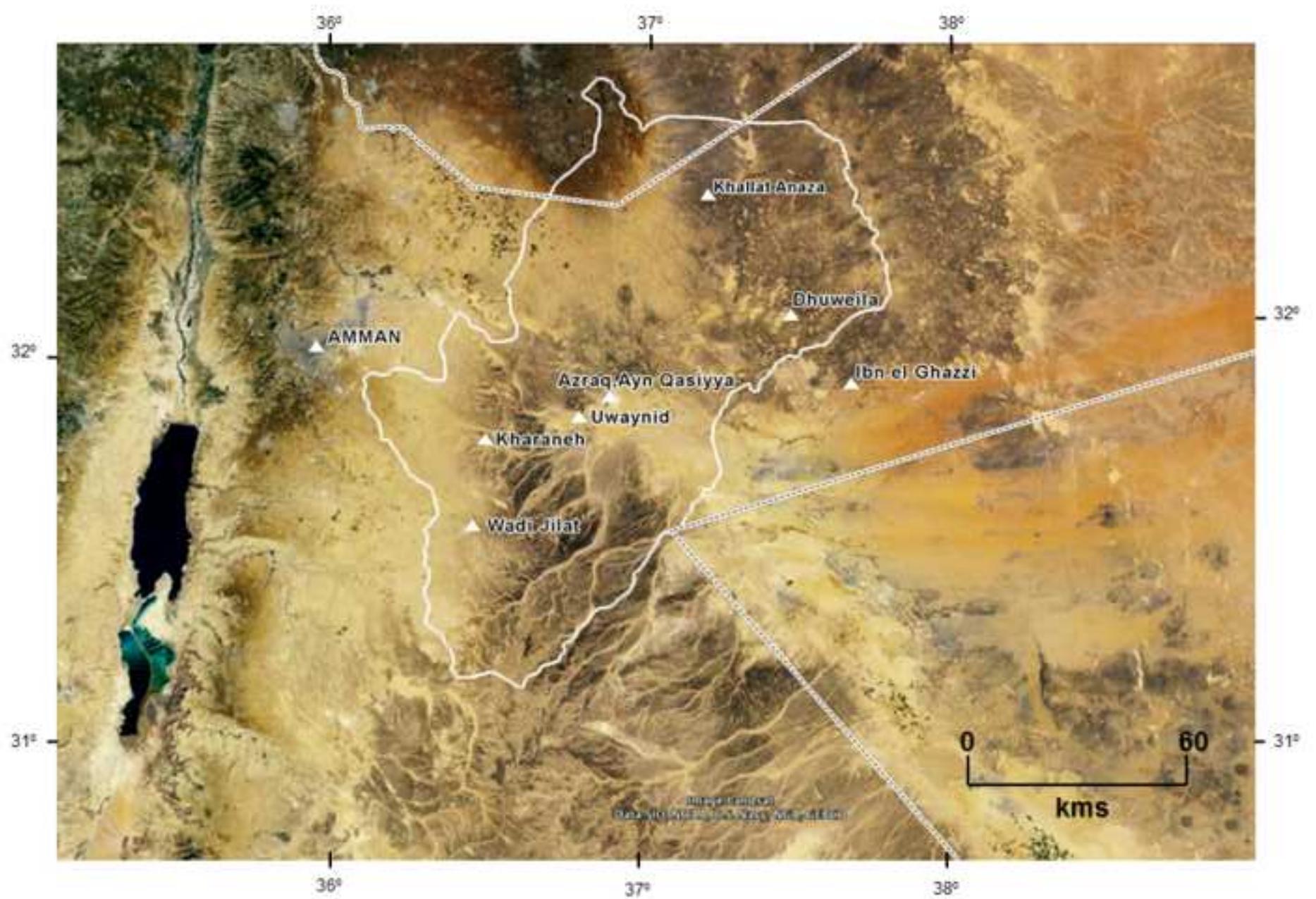
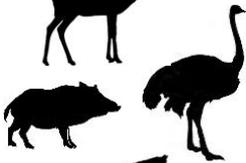
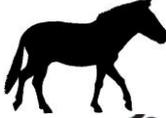


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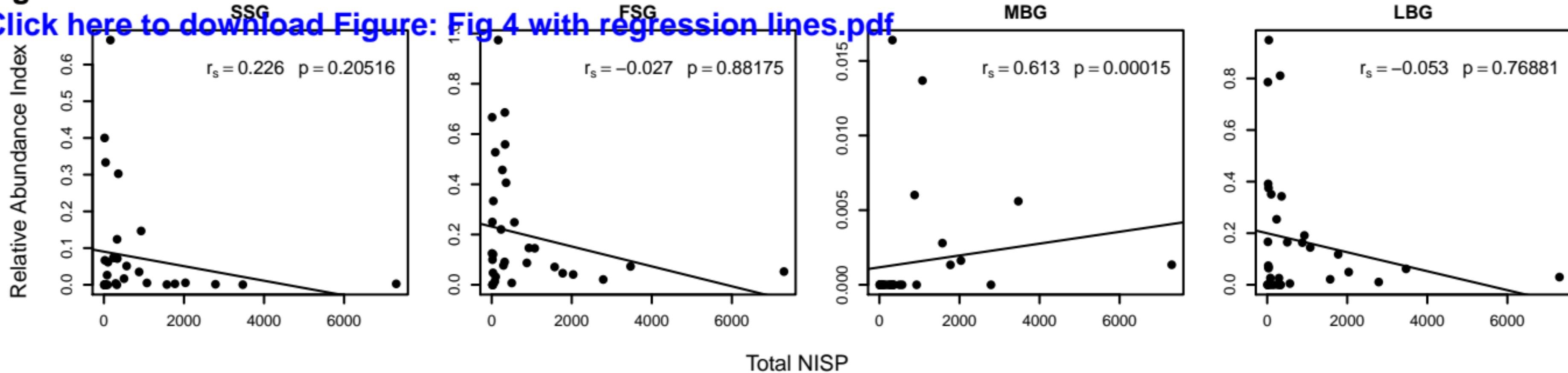
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Figure 3

	<b>Body weight</b>	<b>Escape speed</b>	
Birds	0.5/5.0	fast	
Hare/Fox	1-1.5/3-11	fast	
Tortoise	1	slow	
Gazelle	15-25	fast	
Boar/Ostrich	60-200/70-145	fast	
Equid	200-300	fast	
Cattle	700-900	fast	

# Figure

[Click here to download Figure: Fig 4 with regression lines.pdf](#)



Figure

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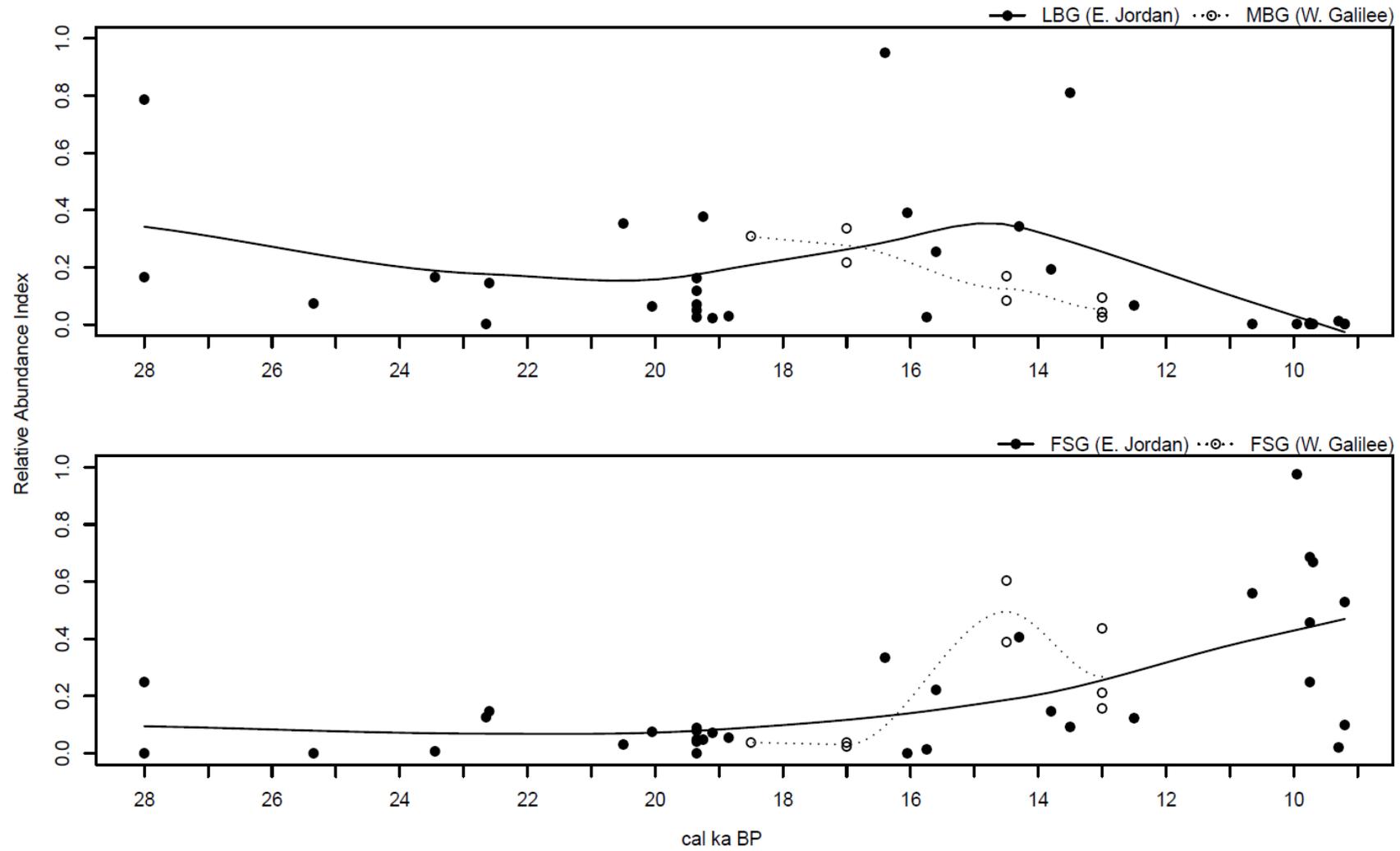


Figure 5 (a, top; b, bottom)

Figure 6

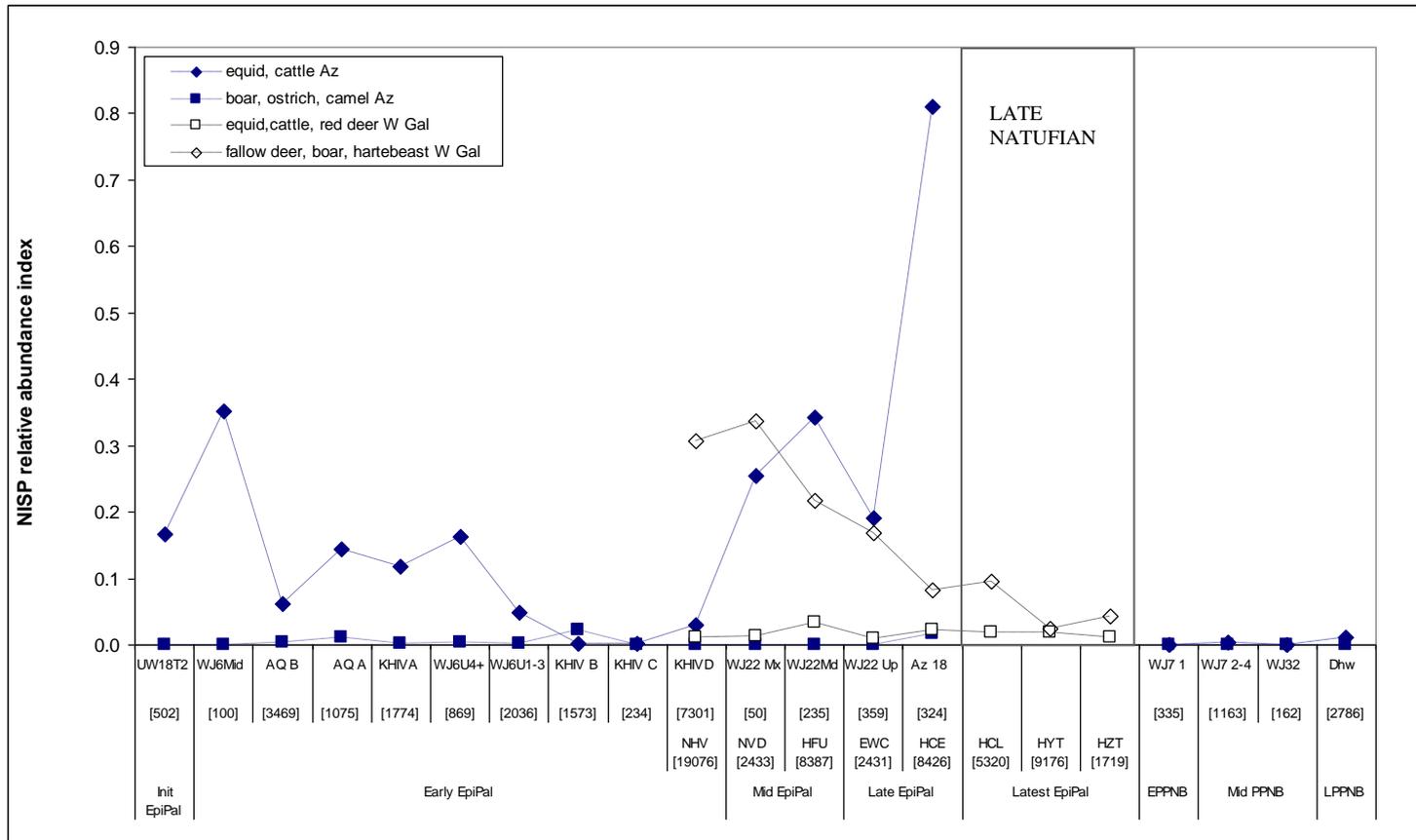
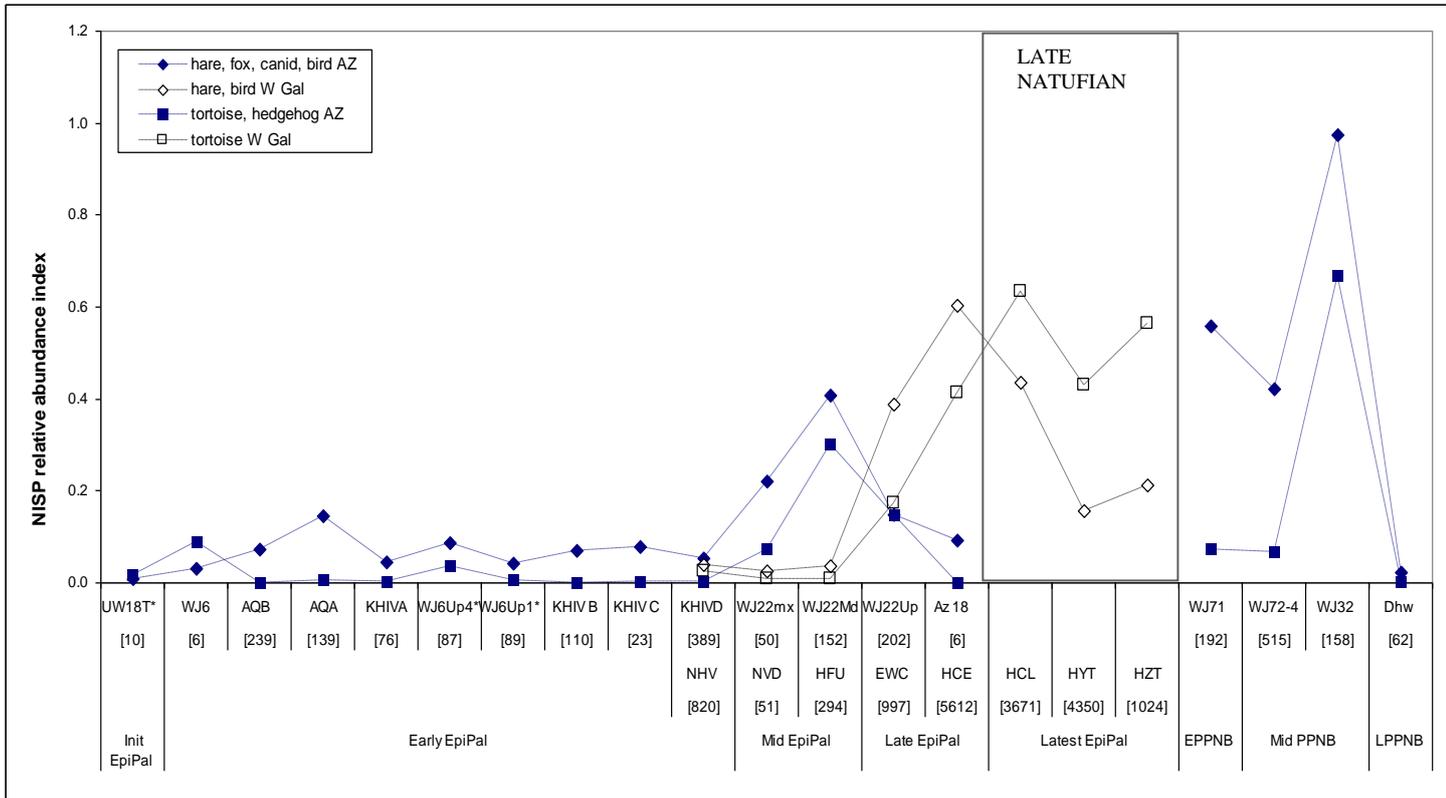


Figure 7



Figure

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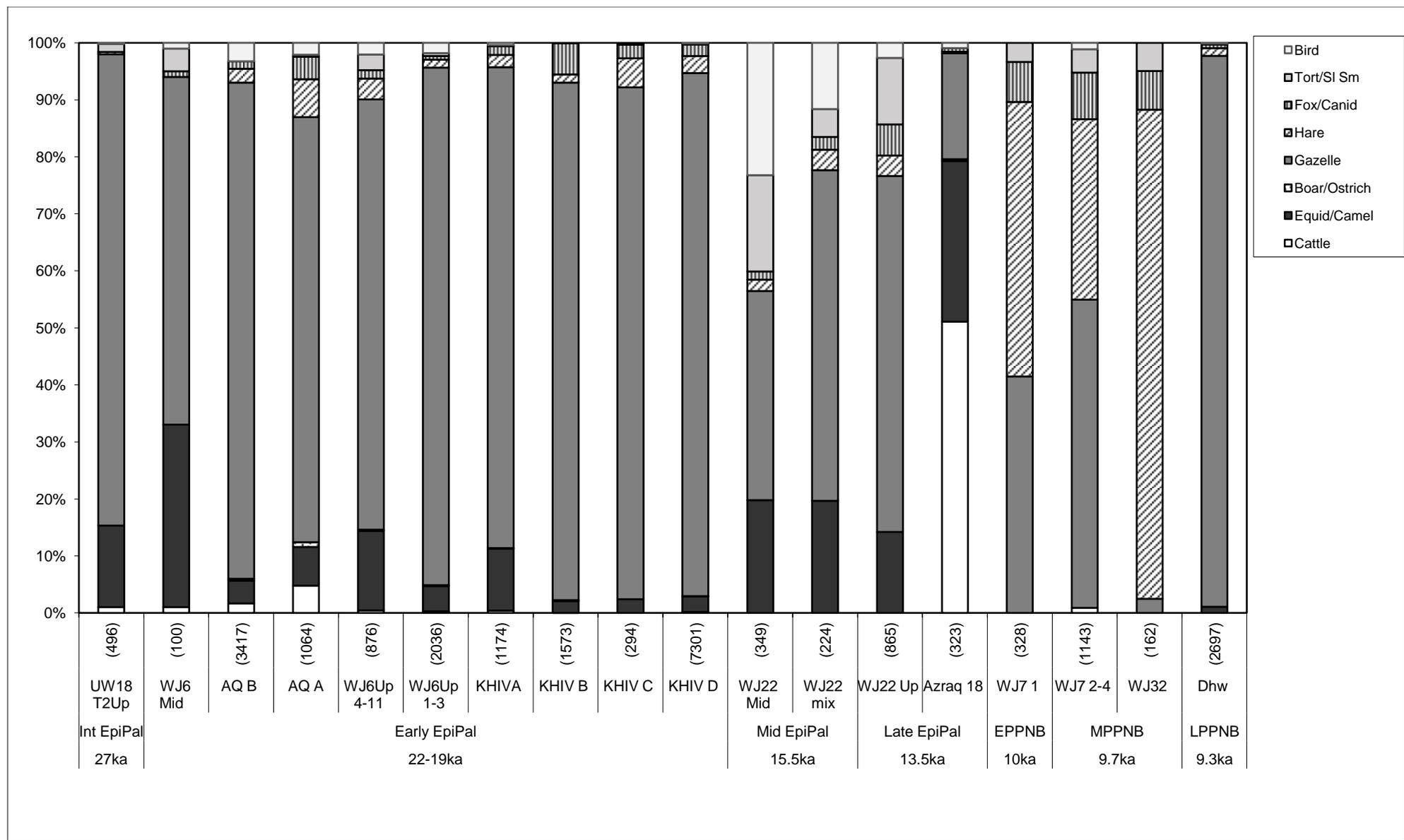


Figure 8

Figure 9

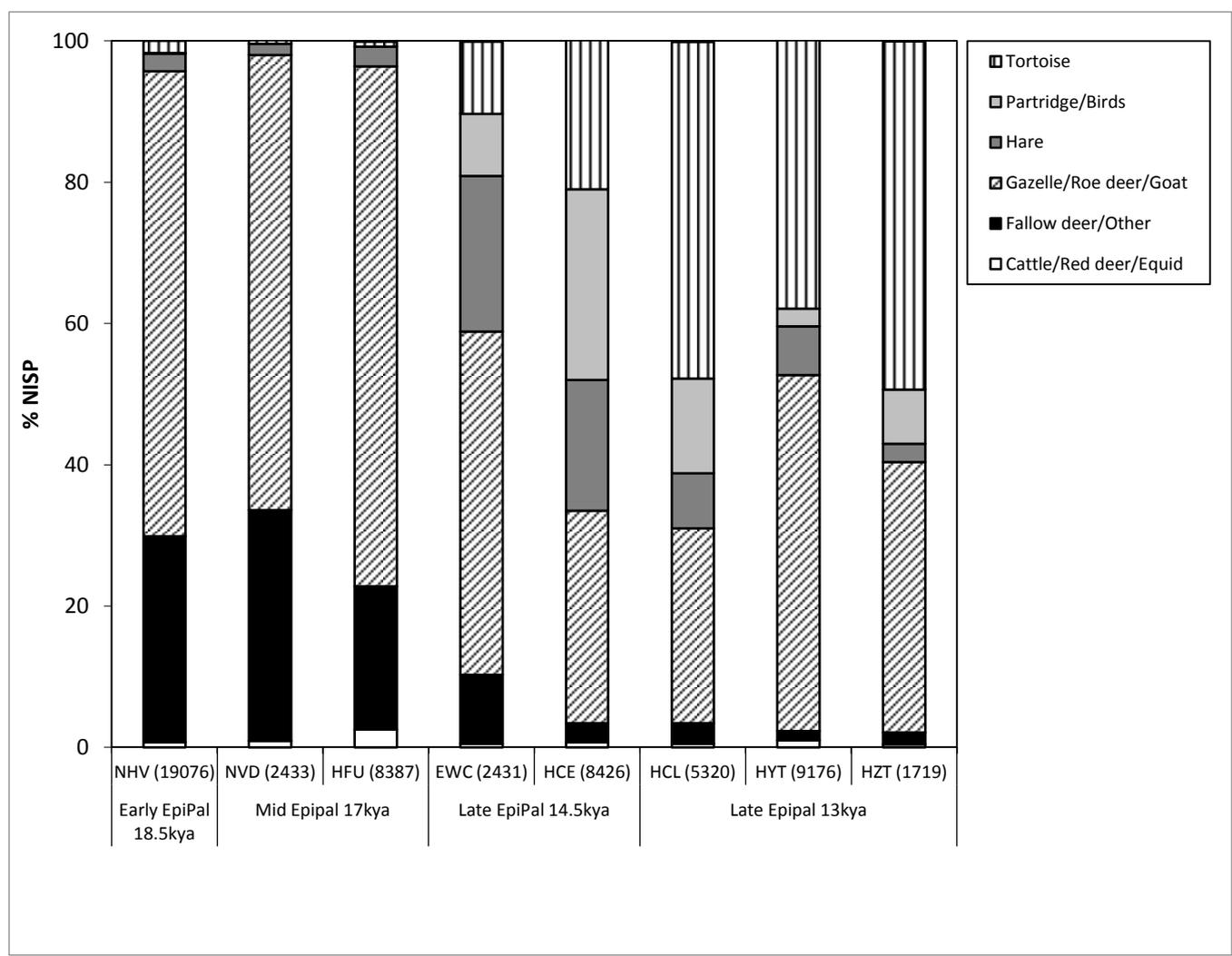


Figure 10

