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IN SEARCH OF A LOCAL PALAEOENVIRONMENTAL RECORD:

COMBINING ARCHAEOBOTANY AND STABLE CARBON ISOTOPES TO INVESTIGATE LIFE, OCCUPATION PATTERNS AND WATER STRESS AT THE EPIPALAEOLITHIC SITE OF KHARANEH IV IN THE AZRAQ BASIN, JORDAN.

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Abstract

This thesis employs two approaches to investigate water stress at the early and mid Epipalaeolithic site of Kharaneh IV in the Azraq Basin, Jordan. Firstly, the archaeobotanical analysis explores the local environment by using the ecology of identifiable charred seeds to indicate water availability (autoecology). Included alongside this is a seed catalogue, which presents the unique archaeobotanical assemblage recovered through sampling. Secondly, to further explore the local palaeoenvironment and due to the potential broad hydrological tolerances of some species, stable carbon isotope $\delta^{13}C$ analysis of the archaeobotanical remains is used to track changes in water stress during the occupation of the site. These analyses provide a complementary approach to traditional archaeobotanical studies. Combined, these data offer considerable insight into questions about the local environment, particularly water stress, and the potential use of plants during the occupation of Kharaneh IV. The results presented here demonstrate that Kharaneh IV experienced variable water stress throughout its occupation, with a drying out of the site coincident with the end of occupation. This signature of drying is found within both the isotopic and autoecological analyses, providing multiple lines of evidence for this pattern. This thesis serves as a case study for the usefulness and inferential power of multi-method approaches that combine archaeobotanical and isotopic analysis.

Acknowledgements

In October of 2012, I stood on the mound of Kharaneh IV and looked down at my feet which were surrounded by thousands of lithics and shattered bones, evidence of a time of prosperity and life in this now dry and inhospitable landscape. I was fascinated by the idea that a landscape so dry and harsh could have once been a wetland refuge that supported so much life. Five years later, I find myself about to submit the culmination of my archaeobotanical and isotopic contributions toward trying to better understand what life was like for the inhabitants of this Epipalaeolithic site. I am indebted to so many fabulous people who have supported me along the way, without whom I would have certainly abandoned ship. Here, I would like to thank and reflect on those people who have supported and helped me through this endeavour.

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"You did everything to bury me, but you forgot that I was a seed."

– Dinos Christianopoulos

Chapter 1. Introduction

1.1. In search of a local palaeoenvironmental record

The Epipalaeolithic period in the Levant has been the focus of much interest (e.g. Blockley and Pinhasi, 2011; Colledge 2001; Byrd *et al.* 2016; Maher *et al*., 2011, Maher *et al*. 2012) as patterns of human occupation and technological development changed during the environmental shifts of the Last Glacial Interglacial Transition, resulting in the emergence of farming at the beginning of the Holocene (e.g. Rosen, 2007). Despite the large body of research on the transition to agriculture and a sedentary way of living (e.g. Riehl *et al*. 2013, Asouti and Fuller 2013, Wilcox 2013, Richter *et al.* 2011, Purugganan and Fuller 2010, Hillman 2000, Stiner 2001, Savard *et al*. 2006, Bar-Yosef and Belfer-Cohen 2010, Zeder and Smith 2009, Smith 2006, Zeder 2006, Weiss *et al.* 2004a, Byrd 2005, Diamond 2002, Hillman 1996), we still lack substantial archaeobotanical data on the preceding Epipalaeolithic period.

For the Neolithic agriculturalists, water for crop production became central to food production leading to extensive irrigation schemes (Mithen *et al.* 2010). However, for the preceding pre-agricultural societies, water was likely of no less importance, especially in arid regions such as the Levant, and also played a key role in wider resource availability (e.g. Kelley *et al.* 2015, IPCC 2012). Plant productivity and diversity is tightly linked to water availability (Fisher and Turner 1978, Boyer 1982). Plant communities not only provided direct dietary and fuel resources for hunter-gatherers, but also supported herbivore populations, a valuable food source. Thus the subsistence and prosperity of hunter-gatherers, particularly in arid regions, depended on water availability directly through personal use, and indirectly via the surrounding plant community. The link between water and the plant community implies that the study of archaeobotanical remains has much to tell us about water resources, ecological conditions and their potential implications for the lifestyles of hunter-gatherers. Moreover, understanding plant responses to palaeoenvironmental changes may offer insight into future consequences of today's rapidly changing environment.

The site of Kharaneh IV, the focus of this PhD, is raising new and interesting questions about the beginnings of sedentisim. It is atypical of the Epipalaeolithic because of the high density of artefacts accumulated between 19,830 and 18,600 cal BP (Richter *et al.* 2013), including the presence of the earliest known hut structures in Jordan (Maher *et al.* 2012) and an occupation history suggesting repeated and frequent use of the site (Maher *et al.* 2012; Richter *et al.* 2013). There is similar potential for discovery in the archaeobotanical analysis. The exceptionally rare botanical preservation and clear stratigraphy, with obvious living floors, which are missing at other Epipalaeolithic sites in the region (Maher *et al.* 2012; Muheisen, 1988; Garrard and Byrd 1992; Garrard *et al.* 1994) offer the potential for valuable new insights into this evasive time period.

The Kharaneh IV excavations are part of the larger Epipalaeolithic Foragers in Azraq Project (EFAP). The aim of EFAP is to develop a detailed understanding of hunter-gatherer behaviour in the Jordanian Azraq basin and place it within the broader context of cultural transformation in southwest Asia at the end of the Pleistocene (Maher *et al.* 2011). It has already led to discoveries of early hut structures (Maher *et al.* 2012b), material culture and lifeways (Maher *et al.* 2014; Maher *et al.* 2016), along with attempts at placing archaeological sites in their environmental context (Jones *et al.* 2016; Jones and Richter 2011; Ramsay *et al.* 2016; Ramsay and Rosen 2016)

EFAP has been built on a long tradition of research into pre-history in Eastern Jordan (see Chapter 2). More detailed analyses, specifically the archaeobotanical assessment of the recovered plant material, are now needed to better understand the local palaeoenvironmental and human–plant interactions. One of the main aims and objectives of this thesis is to address this need and provide the first ever archaeobotanical data for the site. Kharaneh IV exhibits a rare case of well preserved plant macro fossils, one of the few archaeobotanical assemblages in western Asia dated to the Epipalaeolithic period, providing a rare glimpse into the management of the local environmental during this time. The scarcity of Epipalaeolithic sites with preserved plant material means that detailed examination of those sites with substantial archaeobotanical remains, such as Kharaneh IV, can make a key contribution to debates about the diet, human environment interactions and lifestyle of

hunter-gatherers, while furthering our understanding of this crucial time in human history.

Contributing towards the overall objectives of EFAP, another main aim of this thesis is to identify the local environmental conditions throughout this time period. This is essential for furthering our understanding of Kharaneh IV's development, apparent prosperity and later abandonment. Regional patterns of climate change are largely drawn from proxy records of the western Levant, e.g. Soreq cave (Bar-Matthews *et al.* 1999), but a regional view of a relatively arid glacial period, followed by warmer conditions with more precipitation during the North Atlantic Bølling-Allerød (e.g. Robinson *et al.* 2006), may not be appropriate at Kharaneh IV.

Several lines of evidence suggest increased water availability during the site's early and mid-occupation. Archaeologically sterile sediments directly underlying the occupation horizons at Kharaneh IV consist of clays and silts that include freshwater snails, indicating local standing water just prior to site occupation (Richter *et al.* 2013, Jones *et al.* 2016). In addition to this, sedimentary sequences in the wadi next to the site reveal that these open water, probably shallow wetland, deposits overlap stratigraphically with the early occupation horizons (Jones *et al.* 2016). Zooarchaeological evidence has demonstrated that the site was utilised by large numbers of gazelle, as well as waterfowl (Martin *et al.* 2010; Jones 2011). Paired with phytolith evidence for wetland vegetation (Ramsay *et al.* 2016; Ramsay and Rosen 2016), this suggests easy access to standing water at the site. Lastly, the archaeobotanical evidence from the neighbouring coeval site of Wadi Jilat 6 suggests a moist steppic environment with pools of water (Colledge 2001).

A hypothesis for Kharaneh IVs decline and eventual abandonment is increasing water scarcity, potentially linked to increased evaporation as climatic conditions began to warm at the end of the Pleistocene. There are several lines of indirect evidence pointing to this possibility. Bajjali and Abu Jaber (2001) suggest a lack of significant groundwater recharge in the Azraq Basin after 18,000 cal. BP and Jones and Richter (2011) found sedimentary evidence of a reduction of water levels in the Azraq Oasis during this time period. However, direct palaeoenvironmental evidence from Kharaneh IV is lacking. The archaeological site itself, and the plant remains preserved

within it, therefore become an important palaeoenvironmental resource to test this hypothesis.

As well as questions of site formation and abandonment, understanding and reconstructing water access is a major palaeoethnoenvironmental goal of this thesis. Tsatskin and Nadel (2003) have demonstrated, using the Early Epipalaeolithic site of Ohallo II, how important proximity to water is for hunter-gatherer groups, specifically the access to multiple subsistence opportunities that these locales provide (see also Mithen 2010). By examining local palaeoenvironmental evidence, specifically water stress on site, alongside archaeological data, the findings reported in this thesis expand our knowledge of the relationships between water availability, environmental change, subsistence, settlement and occupation patterns of hunter-gatherers at Kharaneh IV and potentially in the wider Azraq Basin.

To address the aims and objectives outlined above, I use two approaches to investigate water stress at Kharaneh IV. Firstly, the archaeobotanical analysis can offer a better understanding of the environment by using the ecology of identifiable charred seeds to indicate water availability (autoecology). Because species differ in their water requirements, large changes in water availability will result in species turnover in the community (Weiher *et al.* 1998), e.g. wet-adapted species will be replaced by drought-adapted flora. However, this traditional archaeobotanical approach may miss relatively smaller changes in water availability that may not be large enough to cause species turnover, if the species present have broad hydrological tolerances. Thus, just examining species presence and absence could miss small changes in water availability that would affect the abundance and quality of food resources.

Secondly, to address the above, I have used stable carbon isotope $\delta^{13}C$ analysis of archaeobotanical remains to track changes in water stress through the occupation of Kharaneh IV. The $\delta^{13}C$ value of plant structural carbon reflects ^{13}C discrimination during carbon fixation (dependent on the photosynthetic pathway of a species) and the $\delta^{13}C$ value of CO_2 assimilated by the plant (Ehleringer 1991;Farquhar *et al.* 1982; O'Leary 1981). Within a given photosynthetic pathway, the level of ^{13}C discrimination during photosynthesis is linked with the opening and closing of stomata. Plants preferentially use ^{12}C, such that plant $\delta^{13}C$ is light relative to

atmospheric values. In periods of water stress, stomata become more closed, CO_2 flows between atmosphere and plant becomes more difficult and plants are required to utilise more ^{13}C, such that plant $\delta^{13}C$ values approach atmospheric values (Ehleringer *et al.* 1993, Farquhar *et al.* 1989; Farquhar *et al*. 1982; Farquhar and Richards 1984; Stewart *et al*. 1995). The amount of ^{13}C in the plant relative to the atmosphere ($\Delta^{13}C$) therefore gives us a relative measure of water stress; when $\Delta^{13}C$ is high, we can infer greater water availability and when $\Delta^{13}C$ is low, we can infer that water availability was lower (e.g. Ferrio *et al.* 2005; Fiorentino *et al.* 2015; Wallace *et al.* 2013). Isotopic analysis thus provides a complementary approach to traditional archaeobotanical studies that is potentially more sensitive to smaller, yet still culturally important, changes in water stress through time.

Compared to later time periods, archaeological data from the Epipalaeolithic period are relatively sparse. But in terms of archaeobotanical investigations, the data are even more limited as there are fewer than ten sites worldwide that have been sampled for Epipalaeolithic plant remains. The result is a lack of primary data that can contribute to the debates on food consumption and resource management that contributed to the changing modes of living during this period – one of the most important and fundamental cultural, societal, behavioural and technological shifts in human history. The new data presented here therefore provide significant new evidence in this direction that will fill some of the gaps and allow new hypotheses to be put forward.

1.2. Thesis structure

Including this Introduction (**Chapter 1**), this thesis is divided into 15 chapters. I have chosen to use a higher number of chapters in order to break down this vast tome of work into digestible sections that link and build on each other to present this study as an evolving question. **Chapter 2** outlines the archaeological background of Kharaneh IV, providing details about the region, the site's location, cultural setting, and chronology, as well as summarising the major archaeological finds. **Chapter 3** places the archaeological site within the environmental background of the Levant. This chapter summarizes the broad geological and climatic conditions, along with the natural resources, present in the area during the Epipalaeolithic. It also explores palaeoenvironmental proxies currently available for the Epipalaeolithic time period. **Chapter 4** encompasses the archaeobotanical background of Kharaneh IV, placing it

within the existing body of knowledge for the site and the region of the Southern Levant. **Chapter 5** presents my archaeobotanical methodology. **Chapter 6** presents the archaeobotanical results (see: Kharaneh IV Seed Catalogue in Appendix 3). This is followed by **Chapter 7** which presents taphonomical considerations prior to **Chapter 8**, where I offer a discussion about what the plant community suggests the environment was like, the temporal changes on site, how Kharaneh IV fits amongst the other known southern Levantine sites and the potential food and diet inferences that the data allow. **Chapter 9** brings us to the application of stable carbon isotopic analysis to the Kharaneh IV archaeobotanical material. Here, a background of previous work is offered, followed by the theoretical basis on which this approach is based. **Chapter 10** presented the isotope methods and methodological considerations of this study as well as presenting the stable carbon isotope results. **Chapter 11** offers a discussion and some conclusions of my isotope findings. **Chapter 12** discusses and combines the information from the archaeobotanical and isotopic analyses and discusses the strengths and weaknesses of combining traditional archaeobotanical methodology with stable carbon isotopes. I present a synthesis of these two lines of evidence and place these newly combined, multi-dimensional data within the regional climatic context and explore the realities of water stress for the hunter-gatherers of Kharaneh IV. Lastly, **Chapter 13** offers the conclusions of the thesis, some final thoughts, and a discussion of future directions.

Chapter 2. Archaeological Context

2.1. Introduction

With the exception of the nearby Wadi Jilat 6, Kharaneh IV is a uniquely large (~21,000 m^2), multi-phase Epipalaeolithic site with a dense concentration of artefact finds, spanning roughly 1.35m down to sterile soil (Harding 1958, 1959; Garrard *et al.* 1977; Muheisen 1988a, 1988b; Maher *et al*. 2012; Martin *et al*. 2010). The site was first excavated in the 1980s under the direction of Mujahid Muheisen (Muheisen 1988a, 1988b) and since 2008 has been under the co-direction of Lisa Maher from the University of California, Berkeley and Danielle MacDonald from the University of Toronto, in conjunction with the Epipalaeolithic Foragers of Azraq Project (EFAP). The existence, emergence and subsequent abandonment of Kharaneh IV and the data that are emerging from it have permitted us to ask new questions about the palaeoenvironment, mechanisms, and the socio-cultural and economic contexts that allowed for a more sedentary or semi-sedentary lifestyle to emerge in the Near East during the Last Glacial Maximum (LGM). The site adds complementary and partially contradictory evidence regarding narratives of the transition into the Neolithic.



Figure 2.1. Location of Kharaneh IV and neighbouring Epipalaeolithic sites with archaeobotanical material

Kharaneh IV is located at 31° 43' 24 N, 36 ° 27' 15 E, 70 km east of Jordan's capital, Amman, at the western edge of the Azraq Basin within the valley of Wadi al

Kharaneh, which drains eastwards into the central Azraq Basin (Figure 2.1). It sits one kilometre southwest of the Islamic Qasr Kharaneh, at an elevation of 640 m.a.s.l. Both Maher *et al*. (2012) and Martin *et al*. (2010) have noted and, based on a site visit in 2012, I can personally attest that despite slow erosion of the upper-most levels of occupation horizons, the site is still prominent in the landscape, rising into a notable tell in an otherwise desolate landscape. The site's ground surface is scattered with all sizes of flint flakes as well as worked flint cores (Figure 2.2).



Figure 2.2. Photo demonstrating the current ground surface, littered with flint flakes, worked cores and bones at Kharaneh IV. Photo by Leslie Bode 2012.

Due to its unusually large size and high density of cultural material finds, Kharaneh IV was initially deemed a megasite by Goring-Morris (1998). With the exception of the coeval site of Wadi Jilat 6 (see Colledge 2002; Garrard *et al.* 1994), at 21,000 m^2, Kharaneh IV is much larger than any other contemporary Epipalaeolithic site in the region, which usually range between 600 and 1200m^2 in size (Maher *et al*. 2008). Adding to the uniqueness of Kharaneh IV, most Azraq Basin and Levantine sites appear to have been ephemeral, with stratigraphy representing single periods of occupation (Garrard *et al*. 1994), whereas Kharaneh IV's stratigraphy shows evidence for multiple Epipalaeolithic phases (Figure 2.3). Excavations thus far have uncovered rich assemblages of stone tools, worked bone objects, red ochre, marine shell beads, excellent botanical preservation, and the earliest known hut structures in Jordan (Maher *et al.* 2012). They have also revealed exceptionally clear stratigraphy with obvious living floors, which, as Muheisen (1985), Garrard and Byrd (1992) and

Garrard *et al*. (1994) have noted, are missing at smaller Azraq Basin sites. The Kharaneh IV hut structures in particular are significant because of their age, ecological setting and evidence for repeated occupation and potentially symbolic behaviours, such as caching and sub floor burials (Maher *et al.* 2012).

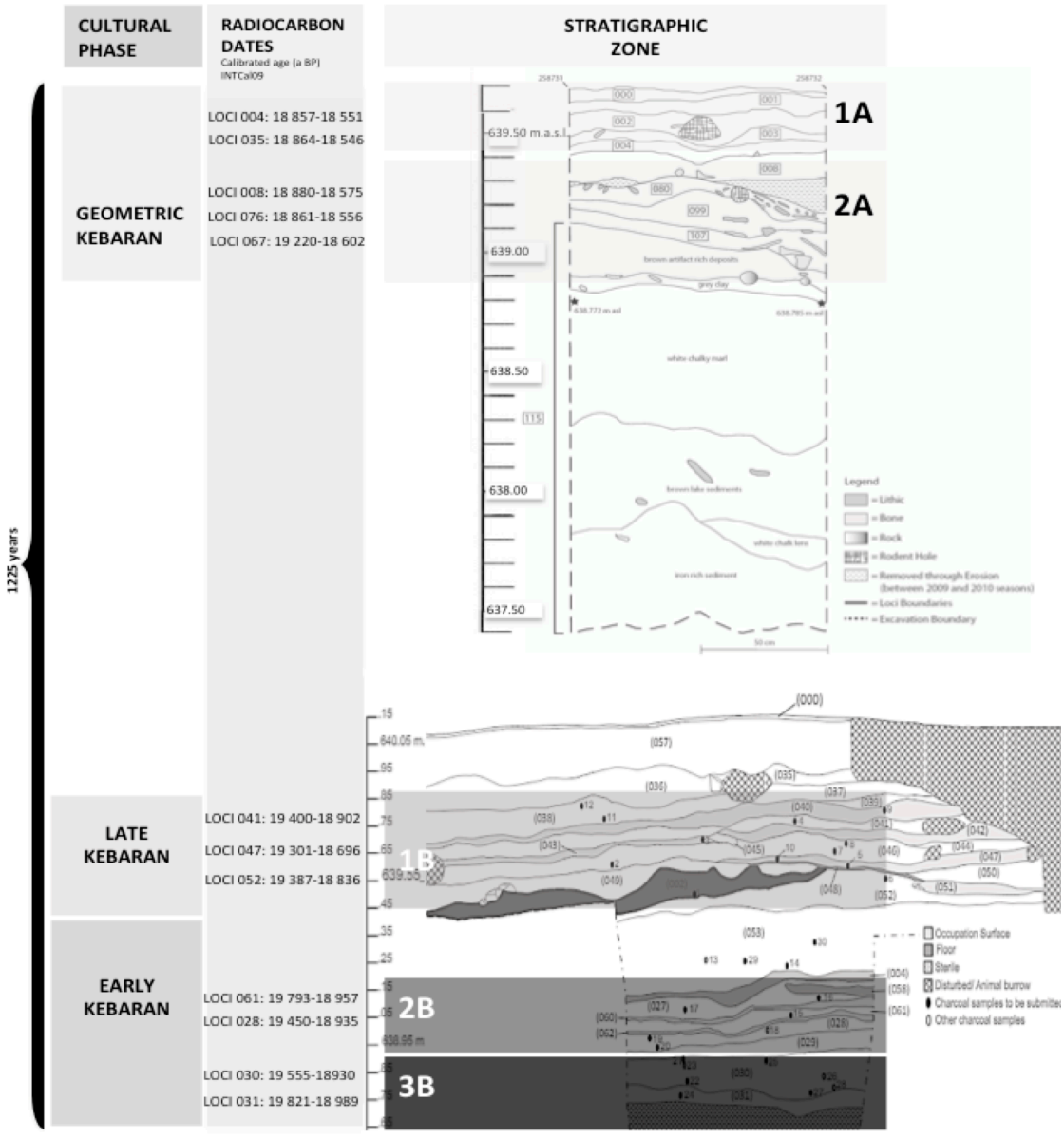


Figure 2.3. Stratigraphy, Muheisen's (1988) cultural phases, radiocarbon dates, and stratigraphic zones for Kharaneh IV

2.2. Excavation history

The site was initially identified and surveyed by Lancaster Harding in 1958 (Harding 1958, 1959). This early survey of the Antiquities of Jordan focused mainly on the nearby Qasr al Kharanah but mentions in passing that "*about 2 km west-south-west of the castle, in the bed of the wadi, is a magnificent Upper Palaeolithic-Mesolithic site, where the ground is covered with thousands of flint implements and flakes*" (Harding 1958).

During the 1970s, Garrard, Stanley Price and Copeland included the mound of Kharaneh IV in their survey of the prehistoric sites in the Azraq Basin (Garrard *et al.* 1977). Their reports consist of a brief assessment of the surface finds, mainly lithics, which are summarised in the discussion on material culture below.

In the 1980s, the first excavations at Kharaneh IV were conducted by the Jordanian Department of Antiquities under the direction of Mujahid Muheisen in 1981 and 1983 (Muheisen 1988a, 1988b). Muheisen's initial discussions of the site described Kharaneh IV as a 'double mound' (Muheisen 1988a) and included references to hut structure traces, living floors, hearths, bone tools, ground stone, human burials, extremely dense faunal material and lithic tools and debitage (Muheisen 1988a, 1988b). Unfortunately, the field documentation from Muheisen's excavations is currently missing. Most of the material from these excavations is currently housed at Yarmouk University in Jordan and has not yet been studied or published. These early excavations consisted of a few small test trenches totalling *c.*15m^2, and the creation of a preliminary surface map of the site. During this work Muheisen calculated that the site was more than 20,000 m^2 in size (Muheisen 1988a, 1988b).

Excavations were renewed during the summer of 2006, with a 3-day survey project completed under the direction of Lisa Maher from the University of California Berkley in conjunction with Tobias Richter from the University of Copenhagen. This survey season mapped the site, and outlined and raised the questions for future work there. The main research questions of this new project were to: explore how has the changing landscape affected land use and settlement patterns during the Epipalaeolithic period; examine the nature, duration and extent of the settlement

during the Epipalaeolithic period; investigate where the inhabitants got their water from; and discern why was this site chosen as a settlement/aggregation place.

Following the survey in 2006, more extensive excavations were renewed in 2008 under the direction of Lisa Maher in conjunction with the Epipalaeolithic Foragers of Azraq Project (EFAP), which is now being conducted through the University of California Berkley and the University of Copenhagen. The 2008, 2009 and 2010 field seasons were the first stages of work by the EFAP team and are the focus of this thesis, as it is during these seasons that the samples were collected. This campaign successfully relocated and reopened Muheisen's old trenches, allowing for correlation of his previous work with the new excavations which have primarily focused on the two mounds, Area A and Area B (Figure 2.4). During these seasons, the team also expanded the old trenches horizontally to expose the site's horizontal stratigraphy and archaeological features, such as hearths, living floors, burials and architecture. The team also excavated a deep probe into one of the trenches extending down until they reached sterile deposits in order to document the extent of the site's vertical stratigraphy (Maher *et al.* 2008, 2009). Since (and including) 2008, 100% of the excavated sediment was collected for flotation. Additional samples were collected for residue analysis, micromorphology and soil analysis, which are now under on-going investigation, including phytolith analysis by Monica Ramsay at the University of Toronto (Ramsay and Rosen 2015, Ramsay *et al.* 2016). These are discussed in both in Chapter 4 and Chapter 14 in order to investigate water stress, seasonality, as well as on-site activities and subsistence practices.

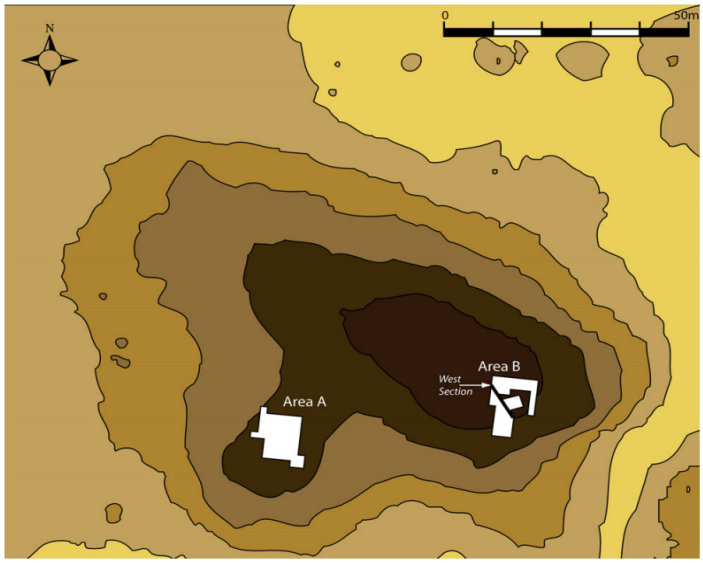


Figure 2.4. Topographic plan of Kharaneh IV showing location of Area B west section and layout of Areas A and B (Richter *et al.* 2013).

The 2010 excavation season at Kharaneh IV uncovered two hut structures (Figure 2.5). Evidence of hut structures is rare in the Early Epipalaeolithic period and these huts pre-date the later stone houses of the Natufian in the Southern Levant (Maher *et al.* 2012). However, it should be noted here that no samples from the hut structure are studied in this thesis, as these were not available.

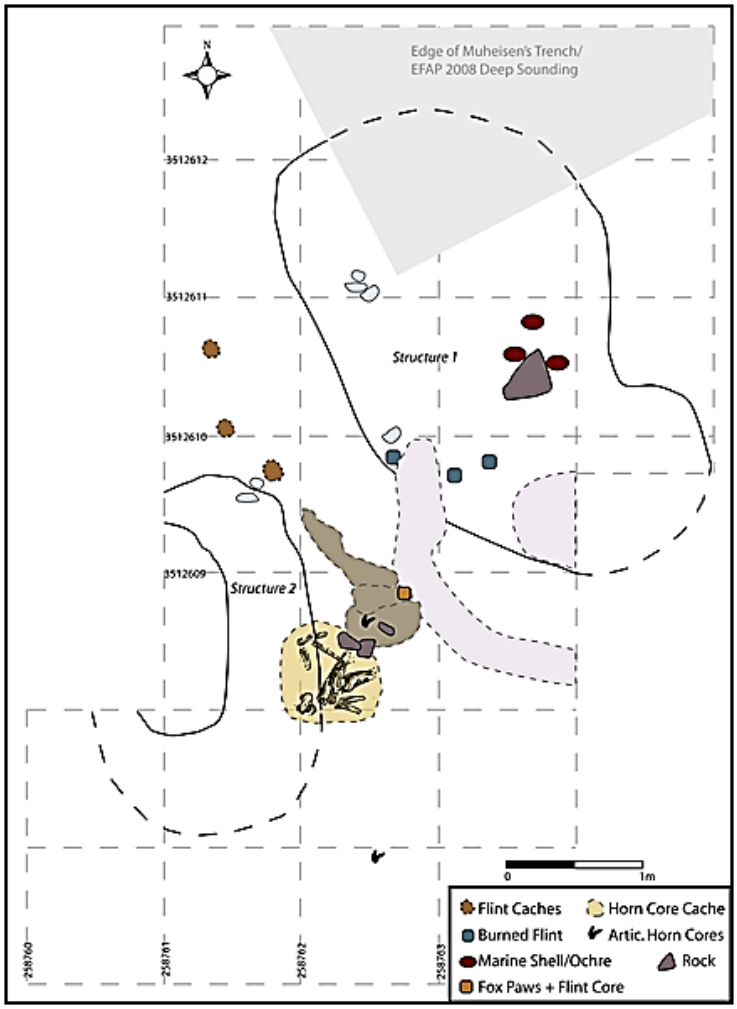


Figure 2.5. Plan drawing of Structures 1 and 2 showing the dimensions of each hut and their position relative to each other (from Maher *et al.* 2012) .

Excavations are on-going and continue to reveal new and exciting data (e.g. Richter *et al.* 2013; Maher *et al.* 2012, 2015, Ramsay *et al.* 2016; Ramsay and Rosen 2016; Jones *et al.* 2016) which are further discussed and contextualised with the data presented here. The 2013 season, for example, focused on exposing, mapping and excavating one of the two hut structures discovered during the 2010 excavation season in Area B. Area B excavations are continuing and are both horizontally and vertically exposing the complete stratigraphic profile of the site.

2.3. Chronology in the Levant

Levantine Epipalaeolithic chronology has been discussed rather intensely (see: Henry, 1988, 1985, 1987, 1996; Bar-Yosef, 1980,1981; Belfer-Cohen and Goring-Morris, 2014; Goring-Morris 1995; Goring Morris *et al*. 2009; Garrard and Byrd, 2013;

Maher et al 2012). Currently, this time period, also known as the Late Pleistocene (note: these periods are not equivalent as one is an archaeological period and one is a geological one) has been divided by Maher *et al.* (2012) and Belfer-Cohen and Goring-Morris (2014) into the following phases:

Late Upper Palaeolithic (ca. 30-24 ka cal. BP)
Early Epipalaeolithic (ca. 24-17.5 ka cal. BP)
Middle Epipalaeolithic (ca. 17.5-14.5 ka cal. BP)
Late Palaeolithic (ca. 14.5-11.5 ka cal. BP).

These phases have been broadly created based on the tool industries they contain, which have been categorised by the stylistic trends in the chipped stone artefacts/ microlithic components (further discussed in section 2.7). Kharaneh IV's lithic industries reveal a Kebaran and Geometric Kebaran culture (Muheisen 1988; Maher *et al.* 2007). Kebaran sites are generally small and, at the well-known Epipalaeolithic site of Ohalo II, they are characterized by kidney-shaped huts (Weiss *et al.* 2004). The Geometric Kebaran extends over a broad geographic region from the Euphrates to the Sinai Desert and generally has features such as pit caches (Goring-Morris 1998).

2.4. Environmental reconstructions

Here the most salient research that examines various aspects of the environment during Kharaneh IV's occupation will be briefly outlined. Chapter 3 focuses on this topic and offers a much more in-depth evaluation, however it is beneficial to the reader to get a brief background at this stage.

Prior to the 1980s, the Azraq Basin, where Kharaneh IV lies, was an oasis – a rich and extensive wetland area centred within a semi-arid steppe and desert landscape (Maher *et al.* 2009, Ramsay and Rosen 2016; Ramsay *et al.* 2016; Jones *et al.* 2016). However, the increased water demand in Jordan has lowered the water table dramatically since then, leaving it with only seasonal water and a mostly desert environment (Gorgi 2006; Ababas 2013; Tadros 1979; El-Kawasma 1983; El-Naqa *et al.* 2007). Moving back in time, Bartov *et al*. (2002) suggested that the end of the Last Glacial Maximum (LGM) likely transformed the Azraq drainage basin into a plant productivity 'hotspot', which was likely a very attractive site for hunter-gatherers due to its proximity to active springs or seasonal water sources in the midst of an arid,

steppic environment. Martin *et al*. (2010), Byrd and Garrard (1990), and Garrard and Byrd (1992) have also pointed out that the Azraq Basin would have been very attractive to gazelle and other animals.

During the occupation of Kharaneh it is likely that the winter and spring months would have seen more rainfall and reduced evaporation than the present day and allowed for the formation of lakes in some areas, while the winter months would have seen animals drawn to these drainage basins in order to access the abundant new vegetation growth (Martin *et al*. 2010). Both Maher *et al*. (2012) and Goring-Morris (1998) have suggested that the area around Kharaneh IV may have formed a settlement refugium during the harsher periods of the LGM. This would have meant a potentially plentiful concentration of subsistence resources for the hunter-gatherers in the region (Martin *et al*. 2010). Martin *et al*. (2010) have drawn a parallel with these events, in relation to what has been demonstrated for the Mongolian gazelle (*Procapra gutturosa*) of the eastern steppic grasslands of Mongolia (Leimgruber *et al*. 2001).

The timing of the abandonment of Kharaneh around 18,600 cal. BP suggests the site may have become no longer suitable or preferred due to local environmental factors; as Richter *et al*. (2013) have noted, it appears that the timing of abandonment may coincide with increasing aridification just after the LGM. As Jones and Richter (2011) suggest for the site of Azraq Basin site of Ayn Qassiya, a shift towards a warmer climate may have led to the disappearance of standing bodies of water due to increased evaporation and more seasonal variations in precipitation. More palaeoenvironmental data are still required as this interpretation of the environment during occupation does not match Bar Matthews *et al.*'s (1997) and Jones *et al.*'s (2007) research suggesting a trend of increased precipitation for the wider region. This disparity may emphasise how broad-scale climatic models can be inaccurate when reconstructing local environmental conditions and their effects on settlement (Richter *et al*. 2013).

2.5. Dating

Initial radiocarbon dating of Kharaneh IV was conducted using bone and charcoal from Muheisen's 1980s excavations, which produced dates between 10,700 and 17,400 cal. BP (Richter *et al.* 2013; Muheisen and Wada 1995). Area A has been attributed to the Middle Epipaleolithic (approx. 14,600-12,500 BP), and Area B to the Early Epipalaeolithic (approx. 22,000-14,600 BP) (Richter *et al.* 2013, Muheisen and Wada 1995) (Figure 2.3).

Richter *et al.*'s (2013) detailed chronological study of Kharaneh IV (and Wadi Jilat 6) using radiocarbon dates from the EFAP excavations in addition to the initial dating from the Muheisen excavations and Bayesian modelling has placed the occupation of Kharaneh IV between 19,830 and 18,600 cal. BP with 95% confidence (Richter *et al.* 2013). These new dates offer an improved dating control for the site and revealed that the site was occupied for a maximum time span of 1,225 years. When combined with the site's large size, high density of finds, and hut structures, this suggests the possibility of multi-seasonal occupation and that Kharaneh IV may have existed as a semi-permanent site before the so called proto-villages of the Early Natufian (Maher *et al.* 2012, Richter et al. 2013). This hypothesis requires further study and the archaeobotanical data presented in this thesis, along with complementary bioarchaeological and stratigraphic data investigate this debate.
For the purpose of this study, I have combined Richter *et al.*'s (2013) dating and the cultural phases suggested by Muheisen (Muheisen 1988a, 1988b) and Maher *et al*. 2012 detailed below (**Error! Reference source not found.**).

2.6. Phasing

Muheisen's excavations during the 1980s documented several occupational phases which, as mentioned earlier, included reference to hut structure traces, living floors, hearths, bone tools, ground stone, extremely dense faunal material and lithic tools and debitage. Muheisen's excavations focused on two main areas: Sounding I was a 2m x 2m trench (R2/60 and S2/60 which are included in Area B of this study) in the main occupation mound that had three superimposed phases (Early Kebaran, Late Kebaran and Geometric Kebaran Phases described below) and a sounding located on the lower mound to the south-west, partly overlying the main mound (Muheisen 1988b, Muheisen and Wada 1995). During Muheisen's first excavation season only $1m^2$ was

excavated, but in 1985 the team excavated a further 12m^2 (Martin *et al.* 2010). Muheisen also identified a fourth phase, unique to this area, which he called Phase D/Geometric Kebaran (and in this study is included in the EFAP Area A) (Muheisen 1988b, Muheisen and Wada 1995).

Muheisen's Kebaran Phase was the lowest level reached in Area B. In this phase the deposits ranged from 30 to 70 cm in depth and a living floor and an associated hearth were found. Microliths dominated the lithic assemblage in this phase and were characterized by bladelets with partial or complete fine retouch and microgravettes with bipolar retouch (Muheisen 1988a). These have been associated with an early Kebaran or Masraqan industry dated to around 20,000-18,000 ^{14}C yr. BP (Goring-Morris 1995) (Table 2.1 and Figure 2.3). In this study, this phase is referred to as stratigraphic zones B3 and B2.

Muheisen's Late Kebaran Phase sits on top of the Early Kebaran Phase and consists of deposits of *c*. 45 cm depth. The lithics in this phase were characterized by obliquely truncated backed bladelets and narrow pointed bladelets both with fine retouch that are probably Classic Kebaran (*c*. 19,000-15,000 BP) (Martin *et al.* 2010). This phase also contained two male human skeletons beneath a distinct occupation surface initially recorded in the 1980's by Rolston (1982). Muheisen also suggested a division or a slightly different variation on this Late Kebaran Phase deposits area which were overlaid by the Late Kebaran phase and were *c*. 30 cm deep where a rectangular hearth and a living floor were found. Backed and truncated bladelets with abrupt retouch were also present (Muheisen 1988a) and are possibly associated with the late Kebaran phase, which Muheisen attributed to around 16,000-14,500 BP.

Table 2.1. Schematic outline of the chronology and distribution of lithic industries in the southern Levant between 23,000-11,000 *cal*. BP (after Richter *et al.* 2011).

Years cal. BP	Archaeological Phases	Lithics industries	
		Mediterranean Levant (West)	Arid Levant (East & Negev/Sinai)
23,000		Masraqan/Late Ahmarian	Nebekian
22,000			Masraqan/ Late
21,000	Early		Ahmarian

20,000	Epipalaeolithic	Kebaran	
19,000		Nizzanian	Kebaran
18,000			Nizzanian
17,000		Geometric Kebaran	Geometric Kebaran
16,000	Middle		Mushabian
15,000	Epipalaeolithic		Early Ramonian
14,000		Early Natufian	Terminal Ramonian
13,000	Late Epipalaeolithic	Late Natufian	Late Natufian
12,000		Final Natufian	Harifian
11,000			

Muheisen's Geometric Kebaran Phase was only present in the south-west part of the mound (EFAP Area A) where the 1985 season revealed a living floor, post holes (suggesting a possible structure), as well as fire hearths with a concentration of occupational deposits. Geometric microliths and frequent large trapezes were also found (Muheisen and Wada 1995). According to Goring-Morris (1995) this lithic assemblage is indicative of the Geometric Kebaran, dated in other areas of the Levant to post 14,500 BP (Martin *et al.* 2010).

2.7. Lithic industries

The Lithic industries for the southern Levant in the Early Epipalaeolithic have been characterised by a dominance of non-geometric bladelet microliths and specifically during the Mid Epipalaeolothic, by the geometric forms of flint tools, which are primarily made up of rectangles and trapezes (Goring-Morris *et al.* 2009). The surface finds reported by Garrard *et al.*'s (1977) survey of the prehistoric sites in the Azraq Basin in the 1970s consisted of microliths with a Natufian appearance, providing evidence of Kharaneh IV being perhaps only temporarily used, but used nonetheless, beyond the PPNA. These microlithic surface finds included nine abruptly backed bladelet fragments, of which two are truncated (Garrard *et al.* 1977). There is also evidence of the microburin technique and a possible lunate fragment as well as some tips of borers and "spiky points" (Garrard *et al.* 1977). A tang end of an early arrowhead type was also found which Garrard *et al.* (1977) has loosely attributed to the PPNA along with bladelet cores, some with axe-like crests as well as some reminiscent of double ended "naviform" cores of the PPNB. Garrard *et al*. (1977) also noted that the reddish mauve colour of the flint is striking. They further suggested that

there was a Natufian and PPNB element to the cores, as carinated end-of-blade and rounded scrapers were also found along with distinctive core tablets, which suggests they could have originated in the Upper Palaeolithic, the Natufian or the Neolithic as they are reminiscent of some scrapers found at Ein Guev III and studied by Bar-Yosef (1970). Garrard *et al.* (1977) also observed that similar core tablets were first seen in the full Aurignacian of the Negev and the Levant coast.

The material culture evidence from the Muheisen and Maher excavations (primarily evidence of the lithic industries) found at Kharaneh IV has been attributed to the Kebaran and Geometric Kebaran cultures of the Epipalaeolithic (Muheisen, 1985, Maher *et al*. 2008) (Table 2.1). Tool making materials, such as tabular flint, was available locally and there is clear evidence of cached lithic tools on site (Byrd 1988, Garrard *et al*. 1988, Garrard and Byrd 1992; Maher *et al*. 2008, Maher *et al*. 2009 Muheisen 1998a Muheisen and Wada 1995; Rolston 1982.) Maher *et al.* (2011) have also suggested, in reference to earlier lithic analysis of sites in the Azraq Basin, that the dates for time periods, such as the Middle Epipalaeolithic, should be placed significantly earlier, overlapping considerably with the Early Epipalaeolithic. Here, a brief overview of the analysis of lithic assemblages from the various past excavations at Kharaneh IV is offered.

Microliths dominated the lithic assemblage in Muheisen's Phase A and were characterized by bladelets with partial or complete fine retouch and micrograveттes with bipolar retouch (Muheisen 1988a), which have been associated with an early Kebaran or Masraqan industry around *c.* 20,000-18,000 ^{14}C yr BP (Goring-Morris 1995) (Table 2.1). Muheisens's Phase B lithics were characterized by obliquely truncated backed bladelets and narrow pointed bladelets both with fine retouch, which are likely Classic Kebaran (*c*. 19,000-15,000 BP) (Table 2.1). The lithics found in Muheisen's Phase C, contained backed and truncated bladelets with abrupt retouch (Muheisen 1988a) and are likely late Kebaran (Martin *et al.* 2010). In Muheisen's Phase D, geometric microliths and frequent large trapezes dominated the lithic assemblage (Muheisen and Wada 1995). Notably one of the trapeze/rectangles examined from the 1985 excavations has a blackened hafting residue along one edge, which has been preliminarily identified as possible bitumen (Figure 2.6). According to

Goring-Morris (1995) this Phase D lithic assemblage is indicative of the Geometric Kebaran dated in other areas of the Levant to post 14,500 BP (Table 2.1).

Preliminary results of the lithic assemblage from Area B, excavated during the 2013 season, were dominated by remnants from the production of narrow and gracile bladelets and non-geometric microliths, traditionally referred to as belonging to the Kebaran industry (Maher and McDonald 2013 site report).



Figure 2.6. Photographic of trapeze/rectangles from Area A, including several pieces with convex ends (a, b, e, i) and pointed ends (h, i, j), one trapeze with a denticulated working edge (g), and one trapeze exhibiting hafting residue (m), after Maher *et al.* (2009).

As Muheisen and Wada (1995) have demonstrated previously, and Maher *et al.* (2009) have confirmed, the chipped stone assemblage from Area A is different from that of Area B as Area A is dominated by trapeze/rectangles of various forms (Figure 2.6).

2.8. Faunal analysis and seasonality

Faunal studies to date have primarily been conducted by Jennifer Jones (2012) and Louise Martin (2010). Martin *et al*.'s (2010) study focused on an examination of the faunal material from Muheisen's 1980s excavations and has significantly added to our understanding of seasonality at Kharaneh IV. The faunal spectrum of species present in the Kharaneh IV Early and Middle Epipalaeolithic levels of excavations is presented here (Table 3). Martin *et al.'s* (2010) study cautiously suggested that the mortality profiles and presence of some migratory bird species may hint at a predominant use of Kharaneh IV in the winter and early spring and also found some evidence for hunting during other times of the year. Martin *et al.* (2010) proposed that many family groups/bands of people aggregated there during particular seasons with the purpose of taking advantage of the high density of gazelle, which are likely to have been present in the winter/early spring seasons. Jones (2012) examined cementum in gazelle teeth found at Kharaneh IV and was able to suggest aspects of environmental seasonality in the occupation layers on the site. Her dental analysis indicated that gazelle were being killed at the site during the autumn/winter as well as the spring/summer. This has provided additional evidence to support the possibility that the site was occupied on a multi-seasonal basis (Jones 2012). Byrd and Garrard (1990) had also previously suggested that Kharaneh IV might have been occupied for longer periods and at multiple times of the year.

Both Muheisen's and Maher's excavations have documented modified animal bone finds. These include a gazelle radius with several parallel incisions (Figure 2.7), a pierced equid metapodial, bone beads, polished bone points, awls and needles, as well as other unidentified polished pieces. Henderson (2009) undertook microscopic analysis of a subset of the distinctive tool marks found on some of the incised bone and found that the incisions found on each individual bone show identical tool marks suggesting they were made with the same tool. Although the function of these pieces remains speculative it seems that the makers of these worked bone fragments either made all the incisions at one time with the same tool or kept the incisor and the bone fragments for some period of time (Maher *et al.* 2009).

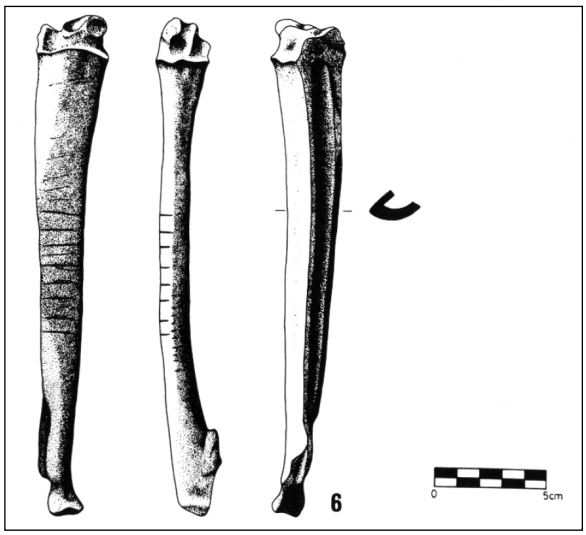


Figure 2.7. Gazelle radius with parallel incisions from Kharaneh IV (from Muheisen 1988b).

Most recently, Henton *et al.* (2016) have conducted a range of isotope analyses on the gazelle tooth enamel apetite from Kharaneh IV to examine the seasonal and spatial distribution of the gazelle found on the site. Using the tooth enamel as an indicator of time and seasonality, they examined the sequence of oxygen isotope signatures to identify patterns of seasonal change. They also used strontium isotope signatures to identify any changes in the animals' locations and carbon isotope signatures were also used to investigate changing feeding habits. Using these three lines of isotopic evidence they found that the gazelle stayed in the general area and only seasonally relocated on a local scale. Despite there being some herd mobility, gazelle were present in the vicinity of Kharaneh IV year round. These findings have added to the conversation regarding the implications of year round access to resources at Kharaneh IV, whether the hunter-gatherers could have inhabited the area year round, or, potentially, aggregated and dispersed as the herds came and went.

2.9. Human burials

Muheisen's excavations documented two Early Epipalaeolithic burials (Muheisen 1983, 1988a, Rolston 1982). Human remains from the Early Epipalaeolithic in Jordan are rare, and to date the only other complete burial has been found at the nearby site of Ayn Qasiyya (Richter *et al.* 2010). The two adult male skeletons from Kharaneh were found below living floors. Rolston's (1982) assessment of these skeletons has shed some light on at least one aspect of the social behaviour of Kharaneh IV's inhabitants.

He revealed that one of the skeletons showed signs of having suffered from severe osteoarthritis during his lifetime as well as other pathologies that suggest he may have had to have been cared for by others (Rolston 1982). This particular individual was also found buried with several large stones placed over his body and two gazelle horn cores placed near the skull. This particular burial agrees with Maher's (2007) suggestion that the features associated with Pre-Natufian Epipalaeolithic burials in the broader region (such as large stone inclusions, stone tools and unmodified animal remains such as gazelle) potentially hint at the elaborate mortuary traditions found in the later Natufian cemeteries. Additionally, an isolated human tibia in a pit with gazelle mandibles and horn cores has been found and suggests the possibility of finding more human remains as excavations continue. As more burials are found our insight into Early Epipalaeolithic health, diet, technology and lifestyle will expand.

2.10. Other bioarchaeological evidence

Shells

Kharaneh IV has produced a large shell assemblage that was initially noted by Muheisen (1988a). Over 1,000 shells from both the early and Middle Epipalaeolithic areas have been collected. Notably shells are more common in the Middle Epipalaeolithic deposits (n>=800). They represent more than 20 species and include *Columbella rustica, Nerita sanguinolenta, Mitrella scripta, Conus mediteranneaus*, and *Antalis* sp. (Figure 2.8) from the Mediterranean and Red Seas. Most are pierced or cut into beads and many show signs of use-wear from having been strung and exhibit traces of red ochre (Allcock 2009). Also of note are the shells originating in the Middle Epipalaeolithic levels that include denticulated fragments of *Pinctada radiata* mother-of-pearl (Figure 2.8).

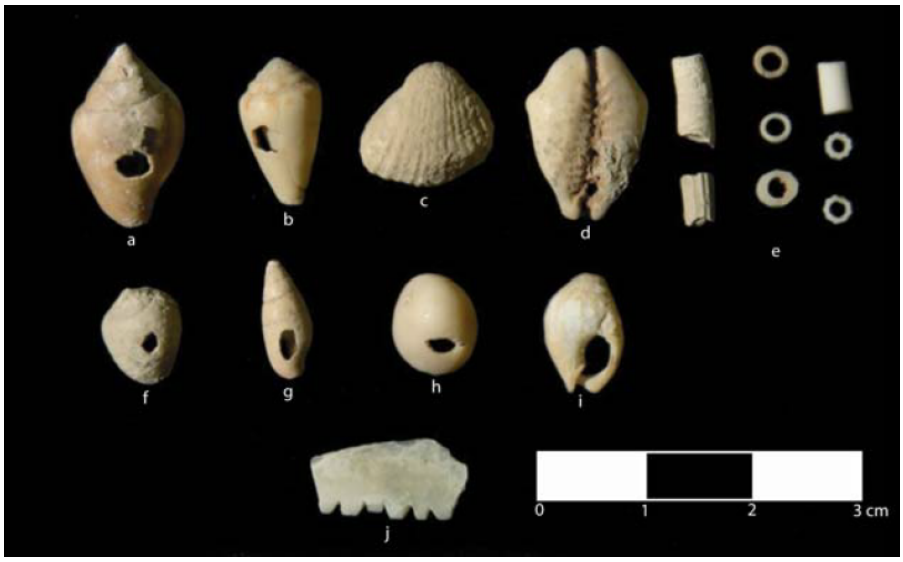


Figure 2.8. Modified marine shells from Area A, including a) *Columbella rustica*, b) *Conus mediterraneus*, c) *Cerastodermaglaucum*, d) *Cypraea erosa nebrites*, e) *Antalis sp*, f) *Euplica turturina,* g) *Mitrellascripta*, h) *Nerita sanguinolenta*, i) *Nassarius gibbosulus*, j) *Pinctada radiata*. (after Maher *et al.* 2009).

Botanical remains

No archaeobotanical analysis (excluding charcoal analysis) has been conducted at Kharaneh IV prior to this thesis. However, the clear evidence of bones, hearths and charcoal indicative of repeated cooking has provided a series of promising archaeobotanical samples studied and analysed here. Complementary archaeobotanical work has been done by Sue Colledge on the temporally similar and nearby Epipalaeolithic settlement of Wadi Jilat 6 (Colledge, 2001). A more detailed account of Sue Colledge's archaeobotanical finds from Wadi Jilat 6 and other relevant sites are outlined in the Archaeobotanical Background Chapter (Chapter 4) included herein. Additionally, some preliminary charcoal identification has been undertaken at Kharaneh IV and has provided supporting evidence for grasslands, trees such as wild almond, chenopods, tamarisk and wild pistachio (Maher *et al.* 2012). These initial results are outlined and discussed in Chapter 4 as well. Further analysis and identification of the charcoal samples is being undertaken by Eleni Asouti and is on-going.

2.11. Aggregation or sedentism?

Mobility and the transition to sedentisim is a key topic in the area of hunter-gatherer research (Maher 2016, Kelly 1992, 2013; Boyd 2006, Byrd *et al.* 2016, Lee and

DeVore 1968; Winterhalder and Smith 1981). Much focus has been placed on risk strategies, storage, social organisation and environmental contexts (e.g. Binford 1980; Kelly 1983, 1992, 2003; Bettinger 1991, 2001; Asouti 2006; Goring Morris et al 2009; Ramsay *et al.* 2016). In particular, with the onset of the early Epipalaeolithic, at sites like Kharaneh IV, the evidence suggests the beginning of residential foraging strategies (Maher 2016). In the southern Levant during the early and mid Epipalaeolithic, hunter-gatherer populations were establishing and maintaining social interactions and trading (Maher 2016, Asouti 2006); at Kharaneh IV, this mobility is reflected in the lithic technology (Maher *et al.* 2012, 2016) and the presence of marine shells. Maher *et al.* (2009) have speculated that these shells from as far away as the Red Sea, present in the Middle Epipalaeolithic deposits at Kharaneh IV, may be a sign of broadening inter-regional social or trading spheres.

The zooarchaeological studies (Jones 2012; Martin et al, 2010; Henton 2016), along with the chronological divisions from the radiocarbon evidence (Richter *et al*. 2013), increase the likelihood that Kharaneh IV was very frequently or even continuously occupied. Martin *et al*. (2010) have suggested that the evidence uncovered thus far at Kharaneh IV can be classified as an 'aggregation' site. These are sites which, according to ethnographic studies, are locations where groups of possibly affiliated individuals come repeatedly and from which they later disperse (Lee 1972). Martin *et al*. (2010) has also touched on the idea that ecological factors, such as resource concentration, were not the only driving force behind aggregation, and that there may be other influencing factors, such as ritual, mate selection or exchange. Referring to Lee (1972) and Conkey (1980), Martin *et al*. (2010) suggested that these factors may have been important in sustaining the aggregation at Kharaneh IV.

As Byrd and Garrard (1992) have argued, occupying an area of ~21,000 m^2, Kharaneh IV is too large to fit the *in situ* occupational spread estimated by Bar-Yosef and Belfer-Cohen (1989a, 1989b) for base camps during the Epipalaeolithic, suggesting that it is a different type of larger scale occupation. We also now know that the site was occupied for a maximum range of 1,225 years and therefore the density of cultural material found on site seems to have accumulated relatively quickly. As Richter *et al.* (2013) have noted, these layers represent a number of occupational

events, similar to those found at a temporally similar site further south in Israel, Ohalo II (e.g. Nadel, 2006), although Kharaneh IV is on a larger scale.

Richter *et al.* (2013) have suggested that the amount of accumulated cultural material suggests that Kharaneh IV was either repeatedly occupied by very large numbers of people, occupied intensively for prolonged periods of time, or somewhat controversially, that it was settled more or less year-round by at least a few people. Further evidence will hopefully inform us on whether we can consider Kharaneh IV as an example of very early sedentism.

Chapter 3. Environmental Context

The fluctuating aridity in the Levant plays a major role in the lives of the people who live there. As highlighted in the introduction of this thesis, understanding this variability is an essential aim of this research, as patterns of past climate change, and how climate may change in the future, will affect decision-making about where people settle in water-stressed climates. Here I present a summary of the available environmental background knowledge about Kharaneh IV and its surrounding region. Where possible, I present information at narrowing geographical scales, including the wider Levant, Jordan, the Azraq Basin, and, specifically, Kharaneh IV. However, the patchy nature of the available data means that environmental information is often lacking at one or more scales. The environmental history of the Azraq Basin and Levant is particularly relevant to this thesis, as one of main hypotheses being tested is whether or not the abandonment of Kharaneh IV was accelerated or forced due to the drying of local water sources, and if this is part of a wider regional trend.

3.1. Topography

The Levant

Four differing longitudinal topographical features dominate the Levantine region (Zohary 1974). The western hill and mountain range is located towards the north of the Levant. Here, two mountain ranges, the Ansariyeh and Lebanon Mountains, form the highlands bordering the coastal plain. Running south, the Lebanon Mountains continue to the Sinai plateau and are divided by two valleys, the Esdraelon and Beersheva Plains. Here the highest points are in the Lebanon Mountains, reaching over 3,000 m. These highlands, along with volcanoes in southern Syria, are an important source of precipitation in the region.

The Coastal Plain consists of the mountains, which slope down to the Mediterranean Sea. In the south, the plain extends out to a maximum width of c. 60 km in the Negev (Zohary 1973, 1962).

The Rift Valley extends from the Amuck plain (North Syria), south along the Orontes Valley, across the Homs-Hama plain to the Beq'a Valley after which it becomes the

Litani River. In the south this includes the Dead Sea, the Gulf of Aqaba, the River Jordan and Wadi Araba. The lowest depression of the Earth's surface occurs in the Jordan Valley, where it reaches a depth of 304 m.b.s.l. (Dead Sea Data Summary, 2015). The Anti-Lebanon Mountains are located in the north east of the Rift Valley and the eastern face slopes down to the Syrian Desert.

The Eastern Mountain Plateau contains the Transjordanian Plateau, which is located to the east of the Rift Valley and rises in the north up to 1,200 m and in the south up to *c*. 1,700 m. In the east it converges with the Syrian and Arabian deserts. It is here that Kharanah IV sits, within the Azraq Basin.

The Azraq Basin

In Jordan, the Azraq Basin lies within the Badiya Region (North-Eastern Desert), which covers about 90% of modern Jordan and borders modern Syria (north), Iraq (east) and Saudi Arabia (south) (Zohary, 1974). It is a plateau with elevations ranging from 600 to 900 metres. The Northeast Jordanian Basalt Plateau covers about 11,000 km^2 in Jordan and the elevation here ranges from 500 m to 550 m and reaches more than 1,100 m at the northern border of Jordan (Al-Bilbisi, 2013*)*.

The Northeast Jordanian Limestone Plateau is a flat desert that extends eastward beyond the eastern borders of Jordan. The Limestone Plateau forms a flat, concave depression with surrounding elevations between 625 m and 800 m. The Badiya contains two main depressions: Azraq and Jafr. The Azraq-Wadi Sirhan Depression gradually rises from 500 m to 700 m in the south-east and here the water collects from adjacent wadis. The Azraq Basin sits in the dry steppe and desert areas of the eastern plateau. The lowest areas of the basin are in the centre beside a structural rift to the south-east. At the centre of the Basin lies the modern extent of the Qa Azraq, which sits at an elevation of 505-506 m. The saddle between the Azraq and neighbouring Wadi Sirhan Basin sits at 530 m. Topographical relief increases near the drainage divides stretching above 900 m in the South West, over 1,000 m in the North East and 1800m at Jebel Druze across the Syrian border (Garrard and Byrd 2013).

The basin's drainage extends 12,800 km^2 (~190 km North to South and 110km from east to west; see Garrard and Byrd 2013). On the limestone, chalk marl hills of the

western, southern, and central-eastern sides of the Azraq Basin, there is an operative dendritic drainage system where the wadis feed into braided channel systems in the low lying areas towards the centre of the basin (Besancon *et al.* 1989; Garrard and Byrd 2013). Here, the sandy/silty depressions along the drainage concourses allow the water from lighter storms to disperse. However, today it is only the water from extremely heavy storms that manages to eventually reach the central playa at Azraq (Garrard and Byrd 2013).

In the lava dominated north, drainage is less efficient and rainwater tends to collect in localized small hollows and depressions, which are sometimes linked to larger wadi courses while some are quite isolated. The larger and major wadis have carved steep-sided gorges through this area (Besancon *et al*. 1989). The Qa Azraq covers *c*. 90 km^2 and can flood to a depth of 2-3 m after heavy winter storms, but currently generally only lasts until late spring (due to evaporation) (Nelson, 1973; Garrard and Byrd 1992).

3.2. Geology

The surface geology in the Azraq Basin is from the Upper Palaeocene and Lower Eocene and consists of a 'Chalk-Limestone Member' (large chalky limestones and layers of nodular chert) (Garrard and Byrd, 2013), which forms the upland areas along the western and central-western extents of the basin. In the centre of the depression, there are gravel plains and low hills formed from limestone, marls and cherts that originate from the Middle to Upper Eocene. Dividing Azraq and Wadi Sirhan, there are a series of marls and sandstones dated to the Oligocene and Miocene, which are intertwined with the basalt flows (see below). Above this sit conglomerates, sandstones, clays and thin-bedded limestone from the Quaternary and Pliocene (Bender 1974; Garrard and Byrd 2013).

The northern extents of the Azraq Basin are covered by basalts and localized tuffs, which reflect a segment of the 45,000 km^2 volcanic plateau extending from the region of Galilee, Hauran and Damascus to the Eastern side of the Azraq Basin to near Jawf in Saudi Arabia (Garrard and Byrd 2013). Bender (1974) outlined six main phases of lava emission and suggested that the surface flows in northern Jordan were related to the last two phases and can be dated to the Miocene and Pleistocene. A more recent

study of the dates of the flows (Baubron *et al.* 1985) in northwest Jordan suggested the dates in the late Miocene and Pliocene. Additionally, dates from localised emissions in northern Israel and Syria suggest Middle Pliestocene and mid-Holocene (Bender 1974; Horowitz *et al*. 1973). The lava present in eastern Jordan is the product of erupted chains of volcanic cones and the tuffs emitted from single or clustered cones, such as Jebel Aritain in the North of Azraq (Garrard and Byrd 2013).

Soil and Sediments

Until the recent publication of the Atlas of Jordan (Myram, 2013), there were no up-to-date comprehensive soil maps for Jordan (Lucke *et al*. 2013). Existing soil surveys that used different classification systems include: Reifenberg (1947), Moorman (1959), Fisher *et al.* (1966), West (1970), Bender (1974), Grueneberg and Dajani (1964), and El-Rihani (1984, 1987). The map below (Figure 3.1**)** presents the Atlas of Jordan's simplified nationwide map of the dominating soil suborders of the respective areas in Jordan using the 11th edition of the USDA soil taxonomy (2010) (Lucke *et al*. 2013).

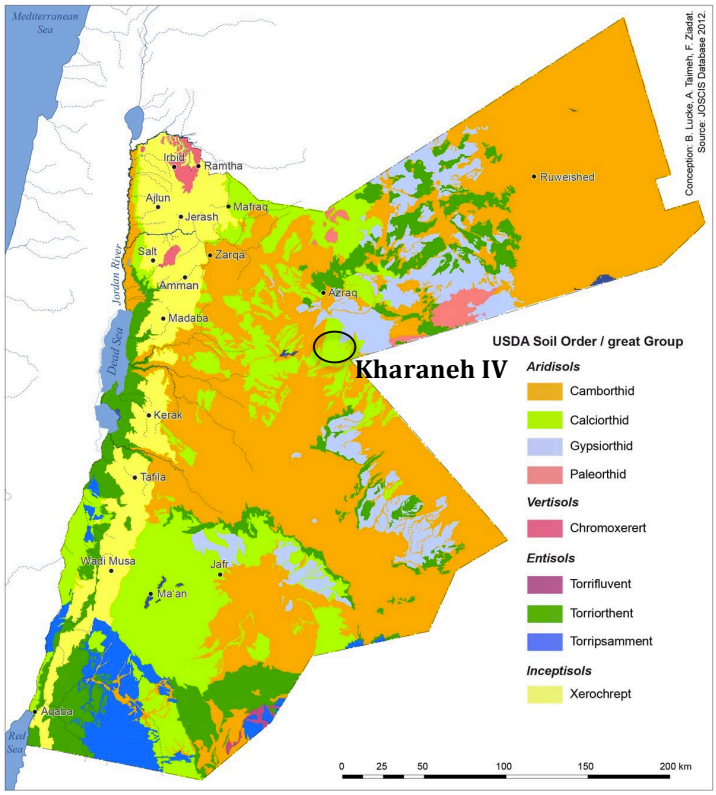


Figure 3.1. Map of soils of Jordon showing location of Khareneh IV (after Luck *et al.* 2013).

The map shows the primary soils of the Azraq Basin to be either:

Aridisols: Soils with aridic (i.e. dry) moisture regime, weak soil development, often enrichment of calcium carbonate and/or gypsum or other salts. The three types present are: *Camborthid*, *Calciorthid*, and *Gypsiorthid* (Garrard and Byrd 2013)

or

Entisols: Very weakly developed, initial soils, mostly A-C horizons or no horizons, sometimes similar to crushed bedrock, shallow and/or rich in stones or gravel. Specifically, *Torriorthent* type is present in the Azraq Basin (Garrard and Byrd, 2013).

Using the aforementioned older soil surveys that offer more specific details of the Azraq Basin (Hemsley and George 1966; Moorman 1959), Garrard and Byrd (2013) placed the soils of the Azraq Basin into eight primary groups (the following list was reproduced from Garrard and Byrd 2013):

1. Along the western and northern rim, where rainfall is higher today and there is more vegetation, there are calcareous or basaltic steppe soils with loess in the depressions. These have a greater profile development than most others in the basin.
2. In the more arid interior there are extensive grey desert soils carpeted with chert gravel reg or basalt hammada. Soil profiles are more poorly developed in these areas.
3. Basalt and occasional limestone lithosols occur where there is little or no soil cover.
4. Alluvial soils ranging from silts and clays to coarse gravel and boulders are found along the drainage channels.
5. Regosols with little or no profile development occur on the gypsum found in low-lying areas around the central basin, on the silt dunes around the playas and on the wind-blown sands in the south-east.
6. The soils within the playas are typically very saline clays or silts and fall into the category of solonchaks.
7. Blueish clay gley soils are found in association with the springs at Azraq.
8. Peats occur in the wetlands at Azraq, consisting mainly of the remains of *Arundo, Typha* and *Scirpus.*

3.3. Climate

The main climatic controls on temperature and precipitation in the Levant primarily come from the mid-latitude cyclones (Cyprus Low) during their eastward passage over the eastern Mediterranean (e.g. Enzel *et al.* 2003, Ziv *et al.* 2006). For Jordan as a whole, the mean annual minimum temperatures are 2-15°C and mean annual maximum temperature is 15-20°C (Palmer 2013). Jordan's summer reaches a peak during August and January is typically the coolest month. Wide ranges and differences in temperature during a single day are greatest during the summer months and have a tendency to increase with higher elevation and distance from the Mediterranean coast (Palmer 2013).

Within the Azraq Basin, the climate is characterized by very hot summers and cold winters (Shehadeh 1985, 1990; El Kawasma 1983; Al-Eisawi 1985). The annual maximum to minimum temperature range (1962-1990) is 36.1-2.8°C (FAO 2010) and frost can occur between late November and April (Garrard and Byrd 2013). Precipitation ranges between 50 and 500 mm annually, depending on the location. More than 90 percent of Jordan currently receives less than 200 mm in annual precipitation (Myriam 2013). The amount of rainfall decreases from north to south and from west to east and varies annually (Jordan National Geographic Centre 1984: 1986). Mean annual rainfall over the Azraq Basin varies from over 200mm in the north and along the western margins to less than 50mm in the south and east (FAO, 2010). Intra-annual rainfall variability is high; half the annual precipitation can fall in a single day (Cordova, 2007). Within the basin, rainfall can also be very localised, affecting only small, proximate areas (Garrard and Byrd 2013).

3.4. Springs and water sources

Abundant springs emerged beside the Azraq Druze and Azraq Shishan, **v**illages on the northern and western sizes of the Azraq playa (Nelson 1973; Garrard 1998). The Azraq springs are fed from the three upper aquifers in the Basin (El-Naqa *et al*., 2007). In the past, prior to over abstraction (see below), these springs contributed to wetland areas adjacent to the Azraq Druze spring (contributing up to 2 km^2) and the Azraq Shishan spring (6 km^2) and both provided significant habitats for migratory

birds (Nelson 1973). Additionally, on the northern and western edge of the playa, smaller springs exist on the silt dunes.

Chemical analysis of the water in the springs suggests that it comes from aquifers beneath the lava canopy to the north (Hemsley and George 1966; United Nations Development Programme 1966). Because the basalts are criss-crossed with fissures, the water can replenish the store in the underlying rock formations which gradually percolates in a down-gradient direction towards Azraq (Hemsley and George 1966; United Nations Development Programme 1966).

Beyond the water available from the few springs adjacent to the playa, the only other water source in the Basin is the surface water contained in the wadi beds and mudflats after winter rainstorms. This source of water is temporary and it drains and evaporates quickly, although some small pools survive in protected places for short periods of time (one week to one month) (Garrard and Byrd 2013). Local pastoralists have hollowed out some of these pools to increase their capacity (Garrard and Byrd 2013). Spring depositive travertines at Qa Umari, Qa Mafarish (Besancon *et al.* 1989) and Wadi Jilat (Garrard and Byrd 2013) indicate that other springs were active in the region during wetter periods in the past.

Azraq wetland reserve

The modern Azraq Basin Wetland sits to the west of Kharaneh IV, in a flat-bottomed playa (Qa al-Azraq) at the centre of the Basin at an elevation of 506 m (Besançon *et al*, 1989) (Figure 3.2; Figure 3.3). Today the Qa al-Azraq is usually flooded by the wadis, which arise after winter storms drain into the basin and form a fresh to brackish shallow lake with extensive muddy margins (Besançon *et al*. 1989).

The Azraq wetland consists of a number of spring-fed marshes and fresh water pools and was, until relatively recently, sustained by a substantial basalt aquifer underlying the basin as well as by runoff from the neighbouring Jebel Druze, 80 km to the north in southern Syria (Woolfenden and Ababneh 2011). Groundwater pumping began in 1963 (Nelson 1973) in order to supply Amman, Irbid and to irrigate local fields. Pumping increased in the 1980s and 1990s and resulted in a drastic drop of the water table and near desiccation of the wetland by 1992, the cessation and near drying of

spring pools by 1994, followed by a near total ecosystem collapse of the wetland in 1994 (Fariz and Hatough-Bouran 1998). In 1994, a rehabilitation of the wetland began on less than a third of the original wetland area, which included the dredging of pools, leaning and deepening of the major contributing wadis and the reverse pumping of water back into the ponds (Fariz and Hatough-Bouran 1998).



Figure 3.2. Extent of the Azraq Basin in relation to Kharaneh IV. Modified from Ramsay *et al.* (2016).



Figure 3.3. Location of Kharaneh IV relative to the Azraq Oasis, from Google Earth.

3.5. Vegetation

The Azraq Basin falls within the Saharo-Arabian biogeographical region (Zohary 1973, 1993; Kasapligil 1956; Long 1957; Al-Eisawi 1985, 1996; Emberger *et al.* 1963) (Figure 3.4**),** covering the generally flat eastern semi-desert and desert of Jordan. Here, today the vegetation cover is low and concentrated in the watersheds of wadis. Zohary (1973) attributes the poor vegetation in the Saharo-Arabian region to climatic and edaphic conditions, which restrict plant growth. Drought resistant xerophytic shrubs and herbs, and short-lived annuals constitute the vegetation here (Colledge 2001). During the summer months, there is even less vegetation and bare patches of exposed soil are common (Berg 1950). Particularity in the mud-flat areas, such as Qa‘ al-Jafr, Qa‘ al-Disi, and Qa‘al-Azraq in the eastern desert, vegetation is remarkably sparse due to water evaporation causing increased salinity and a hard crust that restricts plant life (Al-Eisawi, 1996). Zohary (1973) presents three classes that comprise the vegetation of the Saharo-Arabian region (also noted by Colledge, 2001). These include: *Anabasetea* which includes the plant communities of the hammada, regs and chalky hills; *Retametea raetami* which includes the vegetation growing on sand; and *Suaedetea deserta* which includes the halophitic plants found in the Wasi Arab and Dead Sea areas. The Azraq Basin sits in a salt and mud-flat area surrounded by chert hammadas vegetation with scrub on the basalt vegetation to the north (Figure 3.4) (Palmer, 2013). Several main habitat types, with characteristic vegetation, can be identified within the region (Table 3.1).

<u>Azraq wetland reserve</u>

Today the area surrounding the Qa al-Azraq is classified as Saharo-Arabian (Al-Eisawi, 1996). As Al-Eisawi (1996) has noted, this is reflected in the arid climate and the sparse shrubs of Chenopodiaceae that tend to be associated with annual succulents and grass while, in the Azraq wadis, we find a comparatively dense vegetation with a more diverse range of species. Within the Qa al-Azraq, vegetation tends to be dominated by salt tolerant plants, including *Nitraria retusa* and *Tamarix passerinoides,* as well as halophites that border the Qa, e.g. *Halopeplis amplexicaulis, Suaeda asphaltica*, *Halocnemum strobilaceum,* and also the grass *Aeluropus littoralis* (Al-Eisawi 1996). Around the wetland reserve there is also fresh water vegetation, including: *Phragmites* peat, *Typha domingensis*, *Phragmites australis*, *Juncus* sp. *Imperata culindrical* and *Tamarix amplexicaulis* at the edges. *Sonchus maritimus* and

Inula crithmoides, *Scirpus maritimus*, *Chara* sp., *Ruppia* sp. and *Zannichellia palustris* are also present (Garrard and Byrd 2013, Al-Eisawi 1996). Table 3.2 gives a list of recorded modern vegetation species within the wetland.

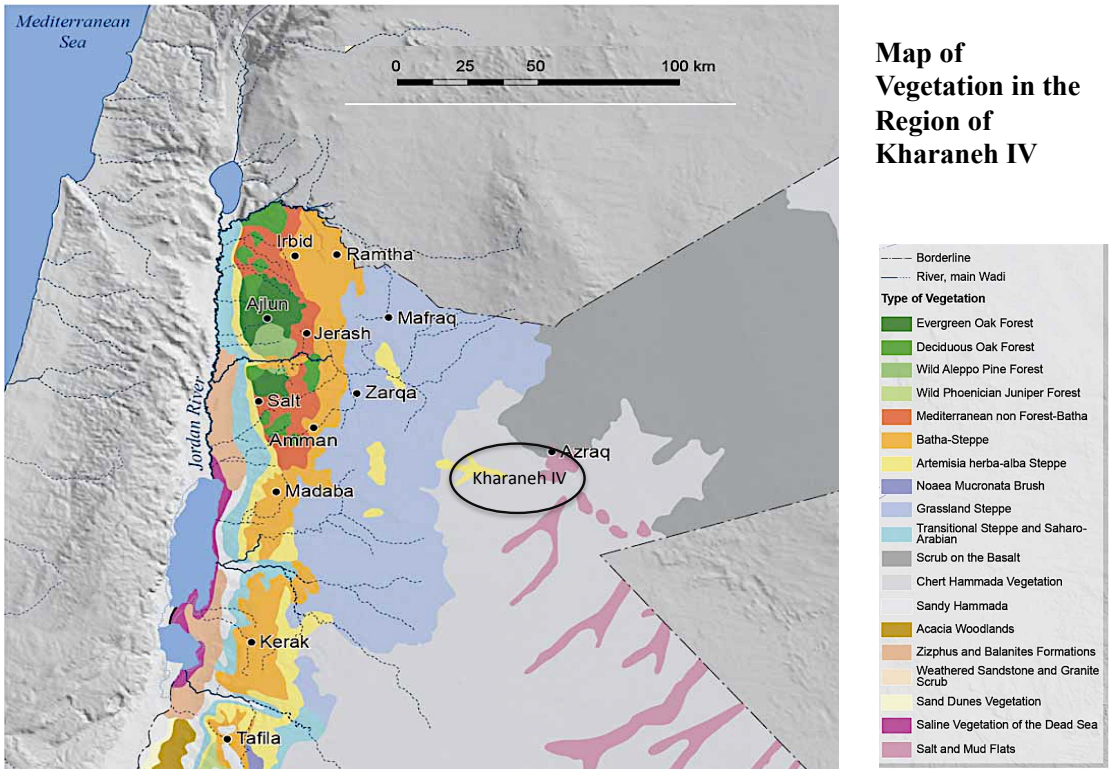


Figure 3.4. Vegetation map for the region around Khareneh IV. Modified after Albert 2003, C. Palmer http://books.openedition.org/ifpo/docannexe/image/4871/img-7.jpg

Modern vegetation degradation in north-eastern Jordan

Over the past *c*. 60 years, substantial vegetation degradation has occurred in north-eastern Jordan, due to extensive and intensive human impact from overgrazing, cutting, and uprooting of perennial xerophyte species for fire, irrigated cultivation, deep ploughing and uncontrolled extension of dry land farming (Sharkas 1994; Sharkas 2001; Tadros 1979). As a result, floristic depletion, soil degradation by erosion, nutrient depletion, and increased salinity are all contributing to continued desertification in the region. Sharkas (2001) illustrates the extent of the vegetation degradation, and primarily blames the contributions of the Jordanian farmers (Fellaheen) and local Bedouin for the extensive desertification in north-eastern Jordan (Sharkas 1994; Sharkas 2001; Tadros 1979).

Table 3.1. Azraq Basin habitats and dominant associated vegetation based on Al-Esawi (1996, 1985), and Gordon Hillman's personal communications with Garrard (reported in Garrard and Byrd 2013)

Habitat	Dominant species
Wetlands: Prior to the large-scale pumping of water to Amman and Irbid, the Azraq spring supported extensive wetlands.	• *Arundo donax* • *Typha angustata* • *Scirpus litoralis* • *Juncus acutus* • *Tamarix jordansis*
Mudflats: Playas with highly impermeable soils have almost no vegetation, while others have a cover of small halophytic shrubs and herbs.	
Silt dunes: The silt dunes around the major playas are characterized by:	• *Nitraria rutusa* • *Tamarix mactrocarpa* • *Tamarix passerinoides*
Wadi systems: The greatest proportion of woody plant growth within the basin is along the wadi systems.	• *Retama raetam* • *Artemisia herba-alba* • *Achillea fragrantissim* • *Atriplex halimus* • *Seidlitza rosmarinus* • *Salsola tetrandra* • *Haloxylon salicornicum* • *Anabasis articulate.* • *Prunus arabicus* • *Pistacia atlantica*
Limestone desert: Plant cover is sparse over much of the chert reg surface, but dwarf shrubs and herbs are found in small silty depressions.	• *Limonium meyeri* • *Inula crithmoides* • *Halocnemum strobilaceum* • *Artemisia herba alba* • *Anabasis articulate* • *Haloxulon salicornicum* • *Haloxulon articulatum.* • *Stipa capensis* • *Schismus arabicus*
Limestone steppe: Around 40-50km west of Azraq is the present boundary between desert and steppe (roughly at the 100mm isohyet). This shows up clearly on satellite images as a shift from a dark surface dominated by patinated chert reg to a light surface of loessic silts held in place by certain species.	• *Poa sinaica* • *Carec stenophylla* • *Anabasis syriaca* • *Noaea mucronata* • *Aellenia lancifolia* • *Aellenia autrani*
Basalt desert:	• *Seidlitzia rosmarinus* • *Anabasis articulate* • *Lucium depressum* • *Achillea fragantissima* • *Artemisia herba-alba* • *Capparis spinosa* • *Salsola vermiculata*

Table 3.2. List of modern vegetation present in Azraq Wetland (compiled from Woolfden and Ababneh 2011, and Al-Eisawi 1996

Nitraria retusa (gharqad)
Tamarix passerinoides
Halopcnemum strobilaceum
Aleuropus littoralis
Phragmites peat
Typha domingensis
Phragmites australis
Juncus sp.
Imperata cylindrical
Tamarix amplexicaulis
Sonchus maratimus
Inula crithmoides
Scirpus maritimus
Chara sp.
Ruppia sp.

3.6. Modern fauna

During the 1960s, Hemsley and George (1966) and Nelson (1973), and more recently Hatough-Bouran and Disi (1991) undertook detailed surveys of the modern era fauna in the Azraq Basin, recording its once relatively rich diversity of animals. These resources have become a particularly valuable record today, as the large mammal population has dropped rapidly in the last 100 years primarily because of the easier vehicle access to the deserts and the use of firearms. Both Montfort (1965) and Mendelssohn (1974) blame the practice of hunting from vehicles using automatic weapons for the stark decline in gazelle numbers during the 1940s.

Until water pumping reached a peak in the 1980s, the wetlands at Azraq were well known as an important layover for migratory birds flying to and from Africa and Eurasia (Nelson 1973). Many other non-migratory animals spent either winter or summer in the oases provided by the wetlands (Ashkenazi 2004; Nelson, 1973). The wadi systems within the Azraq Basin also provided comparatively lush vegetation corridors where a broad range of species, such as game birds, including partridge and

grouse, could thrive. Meinertzhagen (1954) recorded Houbara bustard and Arabian ostrich in the region.

Other animals that may have been hunted in the past include: tortoise, lizards (such as the large monitor lizard) and fish from the Azraq marshes (Hemsley and George 1966; Nelson 1973). According to Garrard and Byrd (2013), who do not source this information "mammals such as wild goat, ibex, oryx onager, sand fox, honey badger, cheetah and leopard may have occurred in the region in the recent past, but documentation is less clear". The following is a list of large mammals resident in the region over the past 40 years: Goitered gazelle, hare, jackal, red fox, striped hyena, wolf, wild cat, caracal, and wild pig (Garrard and Byrd 2013).

3.7. Palaeoenvironment

Pleistocene and early Holocene in the Levant and Azraq Basin

This section consists of a brief review of the available environmental data from the Levant. Numerous authors have recently noted that we still have relatively poor understanding of the local palaeo-environments within the Levant (e.g. Robinson *et al.* 2006; Enzel *et al.* 2008, Woolfeden and Ababneh 2011), with most data focused on the much wider region (Levant and Near East), especially the western Levant. Here I will attempt to pull together all the available evidence together to provide a sequence of past events, as we currently understand them.

Lacustrine sequences

In semi-arid to arid areas of the Syrian and Jordanian Plateau, as well as several deeper basins in the Rift Valley of the Levant, several shallow lake basins have been studied. First discussed by Roberts (1982) and more recently by Develle *et al*. (2011), over the last 30 kyr BP these lakes appear to have peaked in size in the 4-5 millennia prior to the end of the Last Glacial Maximum (LGM) and then diminished relatively quickly after *c*. 22-21 kyr BP (Garrard and Byrd 2013).

Some of these lakes are thought to have re-established themselves on a smaller scale during the Holocene, but are now occupied by seasonally flooding playas. For example, the Palmyra Basin of central Syria reached peak level between 23.1-22.4 kyr BP (19.4-18.9 kyr ^{14}C BP; Sakaguchi 1978); the Damascus Basin of south-west Syria

reached its peak between 28.4 and 22.5 kyr BP (23.6-19 kyr ^{14}C BP; Kaiser *et al.* 1973), and the El Jafr Basin of south-east Jordan may have had a lacustrine phase at 31 kyr BP (26.4 kyr ^{14}C BP), but this is based on a single date (Huchriede and Wiesemann 1968, see Maccumber 2001). A lake that formed in the Wadi Hasa, which drains into the rift valley from the west-central Jordan Highlands, was also at a high level between 20.8 and 22.5 kyr BP (26-19 kyr ^{14}C BPp: Schuldenrein and Clark 1994).

The former Lake Lisan (the Dead Sea) in the Jordan Rift Valley has been more intensively studied. At its height, it extended for 220 km from Hatsuva (located 35 km south of the current Dead Sea) to the northern shore of the Sea of Galilee (Lake Kinneret) (Garrard and Byrd 2013). Recent explorations of the sedimentary and chronological history of Lake Lisan have been carried out by Schramm *et al.* (2000) and Bartov *et al.* (2002, 2003), who analysed and dated sequences exposed in the Perazim and Ze'elim valleys, which drain towards the southwest edge of the Dead Sea. Additionally, Hazan *et al*. (2005) focused on the history of Lake Kinneret and its relationship to Lake Lisan.

Lake Lisan appeared at *c*. 70 kyr BP and early on it stabilised at around 280±10 m m.b.s.l., with frequent falls in level between 48-43 and 38-36 kyr and a slight rise in level between 33 and 29 kyr. At *c*. 27 kyr BP the level rose to -165 m, and from 26-24 kyr, Lake Lisan and Lake Kinneret joined into a single 220 km long lake. It stabilised at the start of the Holocene at about -400±10 m, forming the present Dead Sea (Bartov 2013, Torfstein *et al.* 2013).

Hazan *et al.* (2005) concluded that the fluctuations in the level of Lake Kinneret before and after its connection with Lake Lisan were in synchrony (Garrard and Byrd 2013). Evidence for a dramatic drop in lake levels during the terminal Pleistocene was also supported by both Schuldenrein and Goldeberg (1981) and Macumber and Head (1991), who studied the associated geomorphological components of the tributaries in the Jordan Rift Valley.

Garrard and Byrd (2013) have suggested that the high lake levels prior to the LGM may be connected not only to reduced temperature and evaporation, but also to

increased rainfall (particularly during the period in which Lake Lisan rose dramatically from -280m to -160m between 27 and 25 kyr BP). They suggest that the major falls in lake level after those times appear to relate to cold and dry events. Additionally, Bartov *et al.* (2003), noted that two of the major decreases in the level of the Lake Lisan overlap with the Heinrich II and I events in the North Atlantic, while the other two appear to have happened at the end of the LGM and during the terminal Pliestocene/Younger Dryas. Bartov *et al.* (2003) also argued that because of the Heinrich events and changes in North Atlantic circulation patterns, cold water could have entered the Mediterranean, which may have led to a reduction in evaporation and less precipitation in the Levantine region as a whole.

Speleothems

Bar-Matthews *et al*. (1997; 1999) have made a detailed analysis of speleothems from the Sorec Cave to the south-west of Jerusalem. Using oxygen and carbon isotope signatures and petrography of growth rings in a series of fossil stalagmites that have been dated by the U/Th technique, their records extend back to 60 kyr BP. The $\delta^{18}O$ values are interpreted as reflecting the rainfall regime and temperature at which the carbonate precipitated within the cave and the $\delta^{13}C$ values as a gauge of the type of vegetation cover. Cold peaks identified at 25, 21-19, 165 and 13.2-11.4 kyr BP correspond with Heinrich II, the LGM, Heinrich I and the Younger Dryas events. Their analysis suggests that mean temperature was up to 6ºC cooler during the Heinrich II and LGM, and that rainfall was markedly lower than today. These peaks are illustrated in Figure 3.5 which shows the Lake Lisan levels and Soreq cave $\delta^{18}O$ results (Jones *et al.* submitted 2017)

Fluvial and Aeolian sequences

In the Levantine semi-arid and arid western regions of the Negev and northern Sinai regions, Goldeberg (1986; 1994) has undertaken extensive field studies on colluvial, fluvial and aeolian sequences covering the last 30 Kyr BP. Goldeberg (1986; 1994) has suggested that the widely separated drainage basins revealed here showed two broad periods when aggradation took place, divided by periods of downcutting. Additionally the authors found evidence for the deposition of silts, clays and fine sands by low energy streams during the Upper Palaeolithic (40-22 kyr 14C BP) and the Epipalaeolithic (15-12 kyr 14C BP), however, between 22.6 and 18.3 kyr BP and

in the period following 13.8 kyr BP this line of evidence at archaeological sites became much scarcer. Goldberg (1986) maintained that greater aggradation would have occurred during moister periods than the present and pointed to stratigraphic evidence like the gleying in sediments at Qadesh Barnea and lacustrine deposition in Wasi Mushabi, along with the diverse placement of archaeological sites during those time periods.

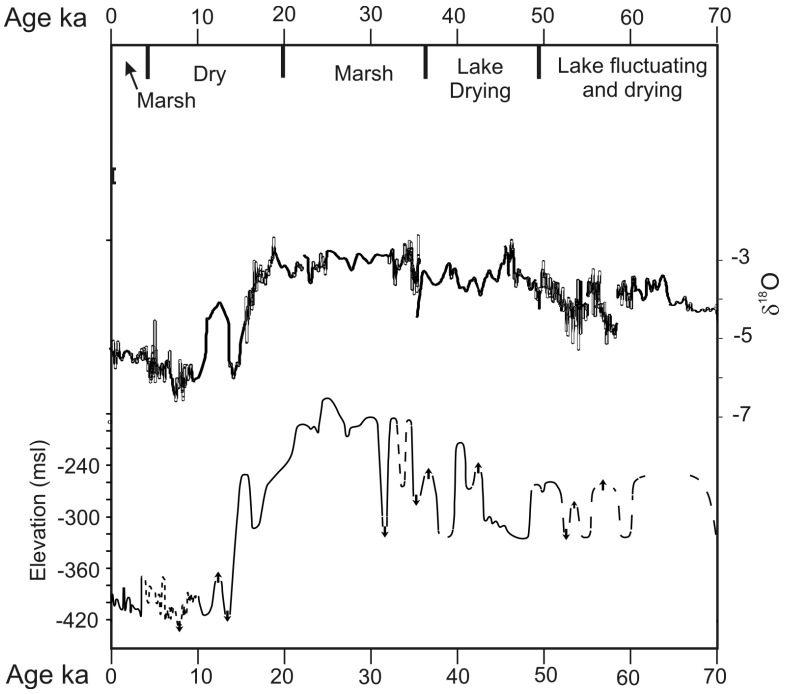


Figure 3.5. Lake Lisan levels and $\delta^{18}O$ from Soreq Cave from Jones *et al.* submitted 2017.

Goring-Morris and Goldberg (1990) provided additional evidence for this environmental chronology using archaeological sites to date the spread of sand dunes (from the Nile Delta) over the northern Sinai and western Negev during the late Pleistocene by documenting their emergence and eastward spread during between 30 and 18.3 kyr BP (25–15 ^{14}C BP). Goring-Morris and Goldberg (1990) concluded that dynamics of linear dune formation suggests arid as well as seasonally windy conditions in the Sinai and Negev at the time of their formation.

The majority of loess in valleys and basins has been re-deposited by fluvial and colluvial processes, making it difficult to establish the history of deposition (Goldberg 1986, Yaalon and Dan 1974). Issar and Bruins (1983) suggest that maximum

accretion likely occurred during wetter periods when rain storms were frequent enough to precipitate dust deriving from the deserts of North Africa and vegetation was more plentiful and could act as a sediment trap.

Using optically stimulated luminescence (OSL) dating, a recent analysis of *in situ* loess deposits surviving in the northern Negev suggested uninterrupted loess accretion from 95-10 kyr BP, although there were variations in the rates through this period (Crouvi *et al*. 2009). Goodfriend and Magaritz (1988) also provided support for Goldberg's general chronology from their study of calcic horizons in the soils of the northern Negev in which they established three periods in which carbonate nodules formed. They have suggested that this happened during wetter, yet still semi-arid conditions which were enough to leach carbonates from the upper layer of sediments but not sufficient to wash them away completely.

The northern Sinai and western Negev were likely influenced by continental weather patterns rather than the area lying directly east of the Mediterranean seaboard (Enzel *et al.* 2008). Confirmation for increasingly moist conditions between 18.3 and 13.8 kyr BP with an apparent break in the Heinrich I period is also available from other sources, such as pollen cores (Tsukada in van Zeist and Bottema 1991; Baruch and Bottema 1999).

Pollen Sequences

There are only two places in the Levant where pollen cores have been taken with semi-continuous coverage of the last 30 kyr BP. Both are previous lakes within the Rift Valley: in the south, the Hula Valley in northern Israel (Meadows 2005; Turner *et al.* 2010; Tsukada 1991), and in the north, the Ghab Valley in northwest Syria (Baruch and Bottema (1999). The current rainfall over the Hula valley is 400-500 mm per annum and for the Ghab Vally, it is *c*. 700mm per annum. The best dated cores from the Hula Valley were analysed by Tsukada (1991) which covers the last 35 kyr BP, and a core studied by Baruch and Bottema (1999), which covers the last 19 kyr. More than ten ^{14}C dates have been obtained from each, and the vegetational sequences match in broad outline. The following are Tsukada's primary observations (for a summary of results see van Zeist and Bottema 1991):

- 30-20 kyr ^{14}C BP: ratio of arboreal pollen (AP) (mainly oak) to non-arboreal pollen (NAP) fluctuated between 30 and 50%. Cool with moist periods.

- 20-14.7 kyr ^{14}C BP: AP at lowest during last 30kyr, accounting for only 20-30% of spectrum. Deciduous oak is the dominant tree species. Rise in steppe species, such as *Artemisia* and Chenopodiaceae. Cold and dry.

- 14.7-10.5 kyr 14C BP: A steady expansion in AP (mainly deciduous oak), becoming more rapid after 15.3 kyr, reaching climax of 75% at 13.3 kyr. Decline in *Artemisia* and Chenopodiaceae. Major increase in temperature and rainfall, particularly during the period equating with the Bølling and Allerød interstadials.

The other pollen core available for the Levant was taken by Niklewski and van Zeist (1970), from the Ghab Valley in northwest Syria, and is thought to extend back to over 50 kyr (Niklewski and van Zeist 1970). Unfortunately there are only three ^{14}C dates from the sequence and the single one from the upper section of the core is problematic (Baruch 1994). Hillman (1996) suggested a new dating for the upper part of the core based on calibrated environmental data from the wider region in order to bring the vegetational history more in line with data from the Hula Valley, specifically that there was a cold, dry phase after the LGM, woodland expansion in the late glacial, a dramatic reduction in woodland in the Younger Dryas and a re-expansion at the beginning of the Holocene. More recently, another core has been taken by a Japanese team (Yasuda *et al*. 2000) who were able to get nine ^{14}C dates extending back to *c*. 17.4 kyr BP (14.5 kyr ^{14}C BP) (Yasuda *et al.* 2000) which supports Hillman's (1996) interpretation.

3.8. Palaeoenvironmental data from Kharaneh IV

Recent sediment mapping and absolute dating work carried out by Jones *et al*. (2016) has suggested that, similar to Jones and Richter (2011)'s work at Ayn Qasiyya in the central oasis of the Azraq Basin, Kharaneh may have had substantial open water at the site. However, no conclusive absolute ages are available, but this open water certainly dates to before 23 kya BP and could have been present later, until at least the early occupation of Kharaneh IV (Jones *et al.* 2016). Pleistocene wetland deposits taken

from Area A were ostracod-rich, contained carbonate-concreted greenish marls and were interstratified with the earliest Early Epipalaeolithic occupations. In Area B, archaeologically sterile, tan-coloured clays with visible carbonate form an abrupt boundary (Jones *et al*. 2016).

The extent and duration of the Pleistocene wetland that deposited clays and silts at Kharaneh IV are yet to be established, but recent work by Jones *et al.* (2016) using satellite imagery has identified the extent of the marl terrace. However, as they and Garrard *et al*. (1985) noted, there are no natural barriers to form a lake in this point on the wadi and there are no visible shorelines along the limestone bedrock on the northern part of the wadi. The depth of the basin is also unknown, but, using current topography, Jones *et al*. (2016) identified a section of the wadi near Kharaneh IV where flowing surface water could have slowed down and pooled. If there had been a natural dam at some point, it could have worn away over the following 20,000 years. The authors also suggest that it is unlikely that groundwater spring activity could be the source of the Pleistocene lake due to the main Azraq aquifers sitting at least 100 m below Kharaneh IV (Al-Kharabsheh, 2000). Jones *et al.* (2016) noted that a substantial drying out of the local environment is reflected in the existence of the silty loam with carbonate concretions, described by Besancon *et al.* (1989) and Garrard *et al.* (1985) as deflated.

Lastly, Jones *et al.* (2016) also concluded that prior and up to 23 kya BP, there was a relatively positive hydroclimatic balance that appears to have already begun its decline by the time Kharaneh IV was occupied. With the nearby central Azraq Oasis providing regular water, at least during the early years of occupation at Kharaneh IV, there would have been substantial environmental resources for the inhabitants to exploit.

3.9. Palaeoenvironmental summary

In summary Kharaneh IV was occupied between 19,830 and 18,600 BP (Richter *et al.* 2013), during the transition between the end of the colder/drier episode of the Last Glacial Maximum (*c*. 23,000 cal. BP), and the warming/wetting phase of the Bølling/Allerød (*c*. 15,000-13,000 cal. BP; e.g. Robinson *et al.* 2006). The oxygen isotope sequence from the Nahal Soreq Cave suggests that this region was undergoing

warming and wetting cycles during the lead up to the Bølling/Allerød, which was just before to the onset of the cooler and drier conditions that came with the Younger Dryas (Bar-Matthews *et al.* 1999; Rosen 2007). In relation to this research on Kharaneh IV, it is important to note that these broad and very regional-scale climatic inferences have been drawn from proxy records from further afield in the western Levant, e.g. Soreq cave or Dead Sea levels (Bar-Matthews *et al.* 1999) and may not capture site specific conditions at Kharaneh IV.

Chapter 4. Archaeobotanical Background for Kharaneh IV and the Epipalaeolithic in the Southern Levant

4.1. Introduction

Here, I offer a summary of our current understanding of hunter-gatherer plant use and the archaeobotanical work carried out thus far on the Southern Levantine Epipalaeolithic (23,970-11,990 cal. BP), encompassing modern southern Syria, Palestine, Israel and Jordan. The aim here is to present and appraise the primary archaeobotanical data currently available for this time period and region prior to presenting the new archaeobotanical for Kharaneh IV. As noted in the introduction to this thesis, the shortage of well-preserved macrofossil data for the Epipalaeolithic is one of the driving forces behind this thesis. Here, to set the scene with the available archaeobotanical information, I present the sparse existing archaeobotanical data from Kharaneh IV. At the time of submission, the available published material consists of phytolith analysis done by M. Ramsay (2016), along with a brief charcoal report. These data provide a good starting point to review the current state of archaeobotanical knowledge of Kharaneh IV, before reconsidering the existing archaeobotanical publications for the wider region and time period. I only briefly touch on the origins of plant cultivation and for further reading on the subject see, for instance, the following recent publications: Zeder (2011); Wilcox (2013), Asouti and Fuller (2013; 2011); Prugganan and Fuller (2010), Fuller *et al*. (2011; 2010); Fuller (2007).

There are very few archaeological sites dated to the Epipalaeolithic with preserved plant remains in the southern Levant (Asouti & Fuller, 2011; Colledge 2001; Hillman *et al*. 1989; Hillman 2000; Weiss *et al*. 2004a, Weiss *et al*. 2004b; Kislev *et al*. 1992; Lev *et al.* 2005; Van Zeist & Bakker-Heeres 1984). The published archaeological sites with macrobotanical remains for this geographical region that date to the Epipalaeolithic total just four. The four Epipalaeolithic sites are: the early Natufian site of Wadi Hammeh 27 (Colledge 2001); the Hayonim Cave (Hopf and Bar-Yosef 1987); Ohalo II (e.g. Snir *et al.* 2015; Weiss *et al*. 2004b); and Wadi Jilat 6 (Colledge 2001) (Figure 2.1). The earlier site (Middle Palaeolithic) site of Kebara Cave (Lev *et*

al. 2005; Bar-Yosef 1992; Schwarcz *et al.* 1989) is also discussed for comparison (Figure 2.1).

Even when considering a broader geographical area than the southern Levant, macrofossil evidence for plant remains other than charcoal are still relatively scarce, while the techniques and methods used in archaeobotanical studies also remain under-developed (Hather & Mason 2002, Pryor 2013). This gap is largely due to the lack of visibility and problems of identification of plant remains due to taphonomical and preservation issues, which are fully discussed in Chapter 8. However, this dearth is also compounded by the fact that systematic sampling strategies have not been employed at many Palaeolithic excavations (Bar-Yosef 1998; Pryor *et al*. 2013; Weiss *et al.* 2004b) as research priorities have been focused elsewhere, notably on the material and structural remains.

Since the more recent excavations at Kharaneh IV have begun, numerous archaeobotanists and archaeologists alike have commented that the botanical finds from this site will likely produce important evidence to add to the extremely limited information on daily life, environment, and society in regards to plant management practices during this period (e.g. Asouti and Fuller 2011; Maher *et al*. 2012; Richter *et al*. 2011). The data presented in this thesis provide us with the ability to better understand the precursor hunter-gatherer societies that enabled the emergence of agriculture.

Commenting on the limited but existing evidence for plant management during the Epipalaeolithic, Asouti and Fuller (2011) have proposed that during the Epipalaeolithic people were likely employing a wide range of foraging adaptations to deal with the locally fluctuating plant resources. By examining the tools associated with plant harvesting and processing in the Near East, evidence in the form of pestles, mortars and sickle blades (Hillman *et al*. 1989; Piperno *et al*. 2004), suggest cereal gathering and plant-based subsistence dating as early as the early Epipalaeolithic (Edwards 2007). The evidence also suggests that the introduction of deep vessel mortars and elongated pestles, which are thought to signal a more intensive processing of plant foods, also occurred during the Epipalaeolithic (Wright 1994, 2005). The presence of plant harvesting and processing tools suggests that wild cereals were

likely used, but not on an intensive scale (Asouti and Fuller 2011). Instead Asouti and Fuller (2011) suggested that it is more likely that these wild cereals were used when other resources became scarce, as their use would have been a labour intensive gathering and processing exercise. .

The presence of ground stone tools at Kharaneh IV has been noted by Maher *et al.* (2008, 2009) and Ramsay *et al*. (2016). However, as of yet, no specific analysis of these has been published. Despite this, their presence hints at some form of plant food processing. The suggestion of an increasing importance of grass resources during this period (Wilcox 2005; Edwards 2007) has been linked with the increased finds of ground-stone tools (see Wright 1991, 1994). However, Wollstonecroft *et al.* (2008, 2009) and Debreeuil and Plisson (2010) have made the practical suggestion that ground-stone tools can be used for other purposes beyond just processing grains such as the processing of other resources like roots and non-food fibres (Hurcombe, 2014). Future residue analysis of the ground-stone tools at Kharaneh IV should provide more understanding of how hunter-gatherers used food processing to improve the nutrition and edibility of resources beyond what was available in the absence of processing or from low-ranked plant foods (see Wollstonecroft, 2011; Smith 2011; Zeder 2012).

Plant processing technology also extends to the use of fire and, although the use of fire by humans dates to approximately 1.0 Ma (see: Berna *et al.* 2012 for discussion on earliest evidence for burning in an archaeological context. see also: Goren-Inbar *et al*. 2004; Dunbar and Gowlett 2014; Wrangham and Carmody 2010), it has been argued based on food processing evidence that it was not until the Epipalaeolithic that humans exploited this technology for plant processing (Wollestoncroft 2008). Munro and Bar-Oz (2005) also demonstrated that by *c*. 126,000 BP there is evidence of bone boiling and animal fat processing, which suggests that the boiling of edible plants was certainly possible during the Epipalaeolithic. Supporting this, Henry *et al*. (2011) have found evidence through the analysis of microfossil calculus that even Neanderthals were consuming cooked plant food. Matthews (2016) offers a review of the changing relationship between humans and fire, specifically in the Zagros or Iraq and Iran and of note here, she concluded that one of key elements that helped lead humans towards the transition to sedentary life was the domestication of fire which enabled greater control over the local ecology. Adding to this, Asouti and Kabukcu (2014) argued that

this domestication/control of fire helped create much of the grass parkland and steppe in Southwest Asia that appear in the Holocene. Earth ovens and pit cooking technology during the Epipalaeolithic have also been suggested by Goring-Morris (1995). These studies lead us to conclude that there were many tools in the hunter-gather's kit for collecting, processing and preparing a wide range of plant resources during the Epipalaeolithic.

4.2. Food, fuel or rubbish?

Interpreting whether or not a plant or part of a plant was actually used or exploited in some way is also problematic, as we can only be sure that it existed on the site. Even if there are many seeds of a certain plant species in a context, this does not mean that seeds were used. For example, for some plants, only the leaves are eaten when they are young, but, later on this same plant will still produce seeds during different seasons when the leaves would have been dry and unpleasant, and therefore the presence of the seeds on site does not necessarily indicate that these seeds, or plants, were a food source at that time. When seeds are present, we can employ as much contextual evidence as possible to infer usage and suggest that other plant parts may have been used as edible resources.

Using fires as a garbage disposal method was, and is, practiced regularly by hunter-gatherer and other mobile and sedentary modern groups. Burning allows for any unwanted, worn, or used bedding, broken baskets, matting, building materials and waste arising from food production and the clearing of plant debris from around the site to be disposed of efficiently (Mandaville 2011; Simms 1988; Miller 1984). Dennell (1976) noted that there is a high possibility that most of our archaeobotanical evidence might be providing us with a better picture of what was thrown away than of what was actually eaten on site. As such, evidence of potential fuel such as wood, shrubs, food processing waste, and animal dung is often found in domestic fires (Bottema 1984; Miller 1984; Van der Veen 2007). Dung is frequently used as a fuel source today by Bedouin peoples in the area as wood is scarce (Mandeville 2011), although we do not yet have enough information to infer whether dung (which if used, would have been collected from the wild gazelle in the area, perhaps out of necessity if wood was scarce) was used as a fuel source at Kharaneh IV. If it were, evidence for this would be present in or around the hearths on site and could provide us with an

additional avenue for plant material to enter the archaeobotanical record. It is, however, it is important to note that plant material included in the charred dung has been exposed to an additional taphonomic factor, as it would have been exposed to a variety of degrading acids during digestion (Charles 1998).

4.3. Kharaneh IV's pre-existing archaeobotanical evidence

To date, the published archaeobotanical evidence from Kharaneh IV is limited to the phytolith analysis publications by Monica Ramsay (Ramsay and Rosen 2016; Ramsay *et al.* 2016) and an initial charcoal report as analysis of the majority of the anthracological material are on-going (Eleni Asouti forthcoming). The following is a summary of the current findings.

Phytolith analysis at Kharaneh IV

The analysis of phytolith remains has provided direct evidence of local plant use and exploitation at many Late Epipalaeolithic sites in the Levant (e.g. Rosen *et al*. 1993, 2007; Rosen, 2011). As phytoliths (which are mineralized elements) are produced by many plants in large quantities, they end up surviving in the archaeological record (Tsartidou *et al*. 2007). The quantitative and morphological analysis of phytoliths can help decipher past human behaviour and the archaeobotanical record on a site (Tsartidou *et al.* 2007; Albert and Weiner, 2001). Using a reference collection, the siliceous phytoliths can be identified and it is possible to determine which plants may have been introduced to the site as well as the approximate quantities of material brought to the site (Albert and Weiner 2001).

Phytolith evidence from the broader area of Kharaneh IV (S.E. Levant) has demonstrated that, by the late Epipalaeolithic, hunter-gatherers were exploiting the rich resources available to them by integrating a wide range of wetland, woodland and steppe/parkland resources and innovatively changing their exploitation tactics towards wetland resources when aridity increased (Rosen *et al*. 1993, 2007; Rosen, 2011; Portillo *et al.* 2010). For Kharaneh IV, specifically, we are fortunate to have recent results published by M. Ramsey and A. Rosen (2016), which also examined phytolith evidence from Ohalo II (archaeobotanical data discussed below). They used these data as a benchmark for comparison with other Eastern Levant sites, including Kharaneh

IV (the other three sites they examined have not yielded any macro-botanical results of which I am aware).

Ramsey and Rosen (2016) used phytolith indicators of ecozone-type (e.g. reeds and sedges indicate wetlands, wild grasses/cereals indicate steppe and parkland, woody plants indicate woodlands) to reveal broad evidence of how foragers used local ecological opportunities. They concluded that Kharaneh IV and Ohalo II were similar, finding that they were both situated next to 'coarse-grained' wetlands (which they classify as marshes and lakes, versus 'fine-grained' meaning stream-bank/riparian), which may have hosted extensive phytolittoral/natural storage larders (see Lee and DeVore 1968). This is reflected in the evidence for high densities of wetland resources. These natural storage larders could have provided substantial dietary and craft/technological needs, which Ramsay and Rosen (2016) suggest would have supported the increasing sedentary occupation of Ohalo II and Kharaneh IV. They suggest that these high levels of wetland exploitation, alongside the existing arguments of Nadel and Werker (1999), Nadel *et al.* (2004) and Maher et al (2012a) regarding hut structures at Ohalo II and Kharaneh, indicate increasing sedentisim at these sites.

Initial Charcoal Analysis from Kharaneh IV

As mentioned, the charcoal analysis from Kharaneh IV is on-going by Eleni Asouti and the only available information on the site's charcoal is found in the initial report undertaken by Phil Austin in 2012, which was conducted with the primary purpose of identification for the ^{14}C dating that led to the publication of Richter *et al.* (2013). Table 4.1 includes the charcoal identifications from Kharaneh IV from squares and loci matching those analysed here for archaeobotanical material. I have also added the appropriate stratigraphic zones (see Figure 2.3) The range of species offers a snap shot into the environment present during occupation. In particular the woody shrub of *Retama* sp.*,* could have provided shade and fuel as could the *Pistacia* sp., which would have also provided a food source. The *Capparis* sp. is particularity heat resistant, and could have provided a food source. Typical signatures of wetland ecology are provided in presence of *Tamarix* sp.

Table 4.1. Number of charcoal fragments per studied sample as well as associated neighbouring squares (*) with samples from the same Loci. Data from: Charcoal Results (done by Phil Austin 2012).

		Area	B	B	B	B	B	B	B	A	A	A	A	A
		Square	AW72	AV72	AZ72	AV72	AY74	AX74*	60.P?	AR42	AR39	AT36*	AT37	AP37
		Locus	74	74	40	73	88	88	2	4	8	34	8	35
Taxon	**(Family FoT)**	**Stratigraphic Zone**	**B2**	**B2**	**B1**	**B2**	**?**	**?**	**B1**	**A1**	**2A**	**A1**	**2A**	**A1**
Capparis sp.	Capparaceae		3				2	13		4				
Chenopod Type 1	Chenopodiaceae					1						7		
Chenopod Type 2	Chenopodiaceae		3	9		6	1	11				6		
cf. *Hammada* sp.	Chenopodiaceae							1						
cf. *Atriplex* sp.	Chenopodiaceae					5			1			3		
cf. *Anabasis* sp.	Chenopodiaceae													
cf. Sueda sp	Chenopodiaceae											1		
Zygphyllum/Fagonia sp.	Zygophyllaceae		1		5		1							
Zygophyllaceae	Zygophyllaceae					2								
Leguminosae	Leguminosae				2	3								
Rhamnaceae	Rhamnaceae		3											
Rhamnus sp.	Rhamnaceae			4								1		
cf. *Cistus* sp.	Cistaceae					3								
cf. *Retama* sp.	Cistaceae					1								
Lamiaceae	Lamiaceae		11	6	3 (cf. Rosemary)	7	4		8			2		
cf. Lamiaceae	Lamiaceae									1	7			
cf. *Acacia* sp.	Fabaceae						1					2		
Tamarix sp.	Tamaraceae		5	2		6	2			3				
cf. *Pistacia* sp.	Anacardiaceae						25	24						
cf. *Cotoneaster* sp.	Rosaceae													
cf. *Vitex* sp.	Vitaceae						3							
Indet.			24	29	15	16	61	51	?	42	18	28	7	5

4.4. Overview of archaeobotanical evidence from Southern Levant Epipalaeolithic sites

Here I present and explore the published archaeobotanical data from sites that are temporally and geographically comparable with Kharaneh IV. Later, in the discussion section, I will compare and contrast these data with the new Kharaneh IV data in order to put the site into context and to present a new, updated summary of archaeobotanical data for the Epipalaeolithic in the Levant.

Kebarah Cave, Mt. Carmel

Kebarah cave is situated on the western face of Mt. Carmel in Northern Israel, about 30km to the south of Haifa at about 60 m.a.s.l. (Bar-Yosef et al, 1992) (Figure 2.1). Opening westward towards the sea, the cave spans 26 m x 20 m and consists of a large chamber with three vaults and a chimney (Goldberg & Laville 1989; Laville &

Goldberg 1989). The Mousterain (Middle and Upper Palaeolithic) layers at Kebarah were excavated between 1982 and 1990 and have been dated to 65-48 kya BP (Schgwarcz *et al.* 1989; Valladas *et al.* 1987). Although this site is somewhat earlier than Epipalaeolithic Kharaneh IV, its archaeobotanical results offer a rare glimpse at Middle Palaeolithic foraging/subsistence and plant exploitation in the Levant in the period leading up to the Epipalaeolithic (Lev *et al.* 2005).

The archaeobotanical results considered here originate from the samples taken by the Israeli-French team that excavated from 1982–1990 (excavations detailed by Bar-Yosef *et al.* 1992). During this time, samples were systematically collected, floated and analysed (Lev *et al.* 2005). A total of 4205 seeds and fruits were recovered, of which 3956 were identified (Table 4.2); the majority of the seeds (78.8%) were from the legume family (Leguminosae). Based on the range of species identified (a total of 51 different taxa), Lev *et al.* (2005) concluded that broad spectrum foraging was a long established behavioural pattern at Kebara. Lev *et al.* (2005) also concluded that, based on the wide range of taxa and seasonality of the archaeobotanical and zooarchaeological assemblages, the cave was likely occupied most of the year, with the exception of its likely abandonment in the high summer when inhabitants would have moved to higher altitudes. This hypothesis is also supported by Valla's (1998) discussion on sedentism and seasonality during the Natufian period.

Table 4.2. List of available data on taxa for Mousterain levels of Kebara Cave (after Lev *et al.* 2005)

Plant name	**Plant part**	**Quantity**
Grasses and Cereals		
Aegilops geniculata/peregrina	seed	2
Avena barbata/wiestii	seed	1
cf. *Brachypodium distachyon*	seed	2
Bromus sp.	seed	1
Hordeum spontaneum	seed	2
Hordeum spotaneum/bulbosum	seed	1
cf. *Cynodon dactylon*	seed	1
Other wild		
Astragalus echinus	seed	1
Bellevalia sp.	seed	2
Carthamus sp.	seed	1
Carthamus tenuis	seed	1
Chenopodium murale	seed	19
Cicer pinnatifidum	seed	1
cf. *Cyperus*	seed	2
Echium angustifolium/judaeum	seed	1

cf. *Euphorbia aleppica*	seed	1
Galium sect. *Kolgyda*	seed	6
Hymenocarpos circinnatus	seed	1
Lathyrus hierosolymitanus	seed	1
Lathyrus inconspicuous	seed	1
Lathyrus sect. *Cicercul*a	seed	16
cf. *Lathyrus* sect. *Cicercula*	seed	56
Lens sp.	seed	247
Malva sp.	seed	1
Mercurialis annua	seed	43
Onosma gigantea	seed	1
Onosma orientalis	seed	5
Pistacia atlantica	nut frag.	503
Pisum fulvum/Vicia palaestina	seed	2
*Pisum fulvum/Vicia narbonensis/peregrin*a	seed	1
Quercus sp.	nut frag.	42
Raphanus raphanistrum	seed	1
cf. *Raphanus raphanistrum*	seed	1
Scorpiurus muricatus	seed	1
cf. *Scorpiurus muricatus*	seed	1
cf. *Silene aegyptiaca*	seed	1
Trifolium sp.	seed	1
Vicia cuspidata/lathyroides	seed	8
Vicia ervilia	seed	8
*Vicia laxiflora/tetraperm*a	seed	1
Vicia lutea/sativa/sericocarpa	seed	1
cf. Vicia narbonensis	seed	1
Vicia palaestina	seed	1
Vicia palaestina/sativa	seed	1
Vicia palaestina/villosa	seed	1
Vicia peregrina	seed	1
Vicia pubescens	seed	2
Vitis vinifera ssp. *sylvestris Vitaceae*	seed	1
Large-seed legumes	seed	712
Medium-seed legumes	seed	1369
Small-seed legumes	seed	877
Unidentified	seed	249
Total		4205

Ohalo II

Ohalo II is a *c*. 2000 m^2, submerged, Epipalaeolithic site dated to 22,500-23,500 cal. BP (Nadel *et al*. 1995, 2002). It is situated on the southwestern shore of the Sea of Galilee in Israel (Figure 2.1). Ohalo II is the richest Levantine Upper Palaeolithic site and has produced evidence of exceptionally well preserved brush huts, hearths, a grave, and a large number of other archaeological finds (see: Bar-Yosef Mayer 2002; Belmaker *et al*. 2001; Kislev *et al*, 1992; Nadel and Werker, 1999; Nadel *et al*. 1994, 2002; Rabinovich, 2002; Rabinovich and Nadel, 1994, 2002; Simmons, 2002; Simmons and Nadel, 1998; Weiss, 2002).

The exceptional preservation of plant material at Ohalo II has been attributed to the fact that the site was charred by a fire which preserved most of the archaeobotanical finds (Weiss, 2002), followed by the successive inundation of the site by the rising waters of the neighbouring lake which sealed the site (Nadel, 2002a; Nadel *et al*. 1995, 2002, 2004). More than 90,000 plant remains have been identified (Kislev *et al*., 1992, 2002a. 2002b; Simchoni, 1998; Weiss, 2002), many to species level with 142 taxa identified (Weiss *et al*. 2008).

Table 4.3. List of edible taxa from Ohalo II (after Kislev *et al.* 1992)

Plant name	Plant part	Quantity
Grasses and cereals		
Aegilops geniculataperegrina	grain	122
Avena barbatata Pott ex Link	grain	4
Avena sterilis	grain	8
Bromus sp.	grain	5
Catabrosa aquatica	grain	66
Hordeum bulbosum	grain	22
Hordeum glaucum	grain	26
Hordeum spontaneum	grain	629
Hordeum pontaneum	rachis node	30
Triticum dicoccoides	grain	21
Triticum dicoccoides	spikelet base	9
Unidentified grases	grain	106
Other wild taxa		
Amygdalus sp.	nutshell frag.	2
Crataegus sp.	stone	12
Nitraria Schoberi	stone	165
Olea europaea	stone frag.	1
Pistacia atlantica	nutshell frag.	2
cf. *Pyrus syriaca*	seed	1
Quercus sp.	nut frag.	43
Vitis vinifera	pip	2
Ziziphus spina-christi	stone frag.	2
Atriplex sect. *Rosea*	fruit	1
Chenopodiaceae	embryo	3
Erodium sp.	seed	1
Lens sp.	seed	1
Malva sp.	seed	7
Scirpus littoralis	nutlet	3
Suaeda sp.	seed	211
Vicieae	seed	1
Arundo/Phragmites	culm frag	1
Chara spp.	nucule	806
Galium sect. *Kolgyda*	fruit 5	5
Hippocrepis sp.	seed	1
Potamogeton sp.	fruitlet	11
Potamogeton pectinatus	fruitlet	42
Styrax officinalis	stone frag.	2
Umbelliferae	fruit 1	1
Unidentified	fruit/seed	88
Total		2463

The plant remains from Ohalo II (Table 4.3; Table 4.4) included *c.* 19,000 wild cereal remains (Weiss *et al.* 2004b), such as wild emmer (*Triticum dicoccoides*) and wild barley (*Hordeum spontaneum*) (Kislev *et al*. 1992; Weiss *et al*. 2004b). These species are noted here because they represent some of the wild progenitors of the later domesticated grasses and offer the earliest evidence thus far for the exploitation of wild grasses as a source of food. Importantly, Weiss *et al.* (2004) proposed that the grains from both small and large seeded grasses were a staple food source at Ohalo II based on the high number of grains found, the fact that the grains were fully mature, and that there are ethnographic parallels for the use of small grained grasses in other hunter-gatherer societies as well as within modern day agriculturalists. Starch residue analysis of ground stone tools from Ohalo II have also provided evidence for the processing of *Hordeum* sp., *Triticum* sp., and *Avena* sp. (see: Piperno *et al.* 2004; Nadel *et al.* 2012).

Table 4.4. The main small-grained grasses at Ohalo II (after Simchoni 1998; Weiss 2002, Weiss *et al.* 2004b.

Plant name	**Plant part**	**Quantity**
Alopecurus utriculatus/arundinaceus	grain	1814
Bromus pseudobrachustachys/tigridis	grain	10 995
Hordeum glaucum	grain	932
Hordeum marinum/hystrix	grain	574
Puccinellia cf. *convolute*	grain	1853
Total		16 168

Due to the exceptional preservation and immense yield of archaeobotanical finds from the excavation, the archaeobotanists working on Ohalo II were able to move beyond just identifying the species present. In conjunction with other archaeologists, they were able to examine the distribution of plant remains within some of the hut structures on site and have demonstrated that even during the early Epipalaeolithic, domestic space can be divided into separate sectors dedicated to different activities associated with the use and processing of plant remains (Weiss *et al*. 2008; Snir *et al.* 2015). This sort of collaborative analysis between archaeologists and archaeobotanists allows for questions surrounding the complexities in social and environmental

interactions, permitting us to gain a more in-depth understanding beyond just dietary reconstructions.

Wadi Jilat 6

Located in the Azraq Basin in the eastern Jordanian Plateau, Wadi Jilat 6 is perhaps the most relevant site discussed here, as its occupation was coeval with Kharaneh IV's and it is located just 25 kilometres (15.5 miles) to the south of that site (Figure 2.1). It is located on the Wadi el-Jilat, which is a tributary of the larger Wadi-Dhobai that drains into the Azraq Basin. Today the site lies at the intersection of the Irano-Turanian dry steppe and the Saharo-Arabian desert (Garrard and Byrd 1992). See also Chapter 3 for more details on the environmental setting of this neighbouring site.

Wadi Jilat 6's occupation has recently been re-dated to 18,503- 13,487 cal. BP (Richter *et al.* 2013), confirming its coeval inhabitation with Kharaneh IV. During excavations, three phases of occupation were identified and lenses of dense Epipalaeolithic culture debris, including flint and artefacts and bone were found (Garrard and Byrd 1992). There were also three surfaces found with compressed and trampled occupational layers, stained with ochre. The surfaces show signs that they may have been 'lipped' at their edges and were likely floors within a structure. Unfortunately, there is only one deposit showing clear evidence of burning, which may explain the relatively low number of archaeobotanical finds (Table 4.5**)** at this site. Microlith flint tools are present in all three phases here as well as limestone and basalt groundstones, shells and worked bone (Garrard and Byrd 1992).

The archaeobotanical remains from Wadi Jilat 6 encompassed a range of seventeen identified taxa (Colledge 2001). The highest number of seeds was from the Chenopodiaceae (chenopods) family, which are common in the steppe-desert environment. The other taxa present also reflect steppe-desert conditions (*Stipa* sp., *Atriplex* sp*, Verbascum* sp.). The proximity to water is indicated by the presence of Cyperaceae (sedges). Notably, both the Cyperaceae and the Chenopodiaceae seeds could have been harvested for human consumption (Colledge 2001). However, at this point, this suggestion remains a hypothesis, as no other supporting data exist. Other plant parts may also have been used; for example, young leaves and stems of *Atriplex* sp. are edible and the fleshy parts and roots of *Verbascum* sp. can be used for

medicinal purposes (Colledge 2001). It has been documented that the perennial woody chenopods are also used as a fuel source in the region and their presence has been interpreted by Colledge (2001) as a possible indicator that the sedges may have been used on site or preferred for their fibrous stems. Colledge (2001) has also suggested that the harvesting of chenopods would have taken place during the spring or in the late summer, early autumn when they are flowering.

Table 4.5. List of taxa for Wadi Jilat 6 (after Colledge 2001).

Plant name	Plant part	Quantity
Grasses and Cereals		
cf. *Bromus* sp.	grain	1
Echinaria sp.	grain	1
cf. *Stipa* sp.	grain	1
Gramineae type 2	grain	6
Gramineae indeterminate	grain	2
Other wild		
Atriplex sp.		22
cf. *Atriplex* sp.		2
Chenopodiaceae/Caryophyllaceae indeterminate		85
single loop Chenopodiaceae/Crucifer		50
cf. single loop Chenopodiaceae/Crucifer		61
Camphorosma type		10
Compositae	kernel	2
Compositae	kernel	7
Schoenus nigricans		18
Cyperaceae type c		1
Cyperaceae type x		1
cf. *Sophora* sp.		1
Verbascum sp.		10
XXX' type		2
Unidentified taxa		64
Total		347

During 1985 and 1986, Gordon Hillman carried out a vegetation survey along the Wadi Jilat. This allowed for a comparison between modern and the current state of the local environment with that of 18-13 kya BP. Hillman's notes have not been published. However, Sue Colledge (2001) has noted the following relevant information from them. Hillman found that, due to overgrazing, it was difficult to define the steppe-desert boundary around the site. He did, however, record a number

of 'indicator' species from both zones: *Anabasis syriaca* and *Noaea mucronata* (indicative of the steppe) and *Seidlizia rosmarinus*, *Halocnemum strobilace um*, *Anabasis articulate* and *Anabasis setiflora* (indicative of desert). Hillman also noted that the landscape was sparsely populated with perennial shrubs, which he observed as mostly being from the Chenopodiaceae family. In the silty soils of the wadi bed, Hillman found slightly different vegetation, which consisted of *Atriplex halimus*, *Verbascum* and several species of *Polygonum,* while in the overgrazed slopes surrounding the wadi he found *Peganum harmala* (which is poisonous to humans) flourishing (Colledge 2001). Hillman's notes offer an interesting perspective on the current state of the ecology, but also provide some potential insight into what may have grown in the area during occupation, but did not survive as macrofossils.

Wadi Hammeh 27

Wadi Hammeh 27 is located on the eastern edge of the Jordan Valley in the foothills of the Ajlun highlands and is perched on the top of a plateau, bounded by the Wadi al-Hammeh and Wadi al-Himar (Edwards 2012) (Figure 2.1). The site has been dated from charred seeds and occupation falls between 12,800/12,500- 11,250 BP (Edwards 2012; Colledge 2001). The site lies within the Irano-Turanian region but is close to the Mediterranean open forest, which is located along the Jordanian plateau and, as Colledge (2012) noted, this would have made the site an attractive ecotonal setting for the exploitation of plants from both vegetation zones.

Nineteen taxa (Table 4.6) were identified among the archaeobotanical remains found at Wadi Hammeh 27 (Colledge 2001). Interpretations based on this assemblage are limited due to the scarcity, low diversity and poor preservation of the remains. However, Colledge has made the following suggestions: wild barley type (*Hordeum spontaneum* type) grains and rachis internode fragments were identified in three samples which can be explained as the site is located in the natural distribution range of wild cereals (Zohary *et al*. 2012). *Aegilops* species along with small-seeded legumes, such as wild lentils (*Lens* spp.), were also found. Colledge (2001) has also suggested that these grains and seeds could have been an important source of food at Wadi Hammeh 27. *Pistacia* sp. trees are common in the woodlands of the area today and would have been available in the summer as fruit/nuts. In addition to this, the resin of the *Pistacia* may have been collected for use. Colledge (2001) noted that

several of the taxa prefer disturbed contexts (e.g. *Lolium* sp.*, Buglossoides arvensis, Malva* sp.*,* and *Matricaria* sp). She also noted that both the leaves and seeds of *Malva sp.* are edible and would likely have been collected in the spring (Colledge 2001). Importantly, the possibility that the leaves and shoots, such as those of *Malva,* were eaten on site or during this time period, reminds us that the range of fresh greens which may have contributed substantially to the nutritional needs of the inhabitants have a very low chance of surviving the taphonomic process and ending up under the microscope of an archaeobotanist. The life cycle of the plant and the season of harvest (i.e. depending on whether the plant was in seed form, young shoots, flowering or mature) also significantly affect the chances of the remains surviving.

Table 4.6. List of taxa from Wadi Hammeh 27 (after Colledge 2001)

Plant name	**Plant part**	**Quantity**
Grasses and Cereals		
Hordeum Spontaneum	grain	3
Hordeum cf. *Spontaneum*	grain	1
Hordeum cf. *Spontaneum*	rachis internode frag.	2
Cereal indeterminate	grain	1
cf. *Aegilops* sp.	grain	1
cf. *Bromu*s sp.	grain	1
Lolium sp.	grain	1
cf. *Stipa* sp.	grain	2
Gramineae indeterminate	grains	2
Species 'X'	grain	75
Other wild		
cf. *Pistacia* sp.		3
Buglossoides arvensis		1
Chenopodiaceae/*Capparis* sp.	spiral embryos	2
Matricaria sp.		1
Lens sp.		1
Leguminosae indeterminate		10
Leguminosae small		2
Liliaceae indeterminate		6
Malva sp.	seed	5
Unidentified taxa		3203
Total identified taxa		120
Total		3323

Despite the small assemblage and diversity of preserved plant taxa uncovered at Wadi Hammeh 27, the identified material offers insight into possible food sources and the

economic resources the inhabitants may have used. The ubiquity of the grains and small legumes as well as the fruits may reflect sources of food. However, due to their scarcity, their relative importance in the diet and predictions regarding seasonality of occupation cannot be inferred unequivocally (Colledge 2012) as there is a chance these are accidental intrusions, or from the surrounding vegetation.

A modern vegetational survey was also undertaken around Wadi Hammeh 27 by George Willcox during the late 1980s for comparative purposes (Willcox, 1992). Willcox (1992) stated that the area had been drastically affected by agriculture, grazing and food gathering. In his survey, he found *Nerium oleander*, *Tamarix* sp., and *Salix* sp. in the wadi beds and in the valley. Higher up, there were degraded open forests with *Quercus ithaburensis*, *Pistacia terebinthus*, *Rhamnus* sp., *Crataegus* sp. and wild *Amygdalus* sp., and on the highest slopes evergreen tree species of *Quercus calliprinos*, *Ceratonia siliqua*, and *Pinus halepensis* (Wilcox 1992). Although *Pistacia* is the only taxon present in both the archaeological and archaeobotanical finds, it is possible that all of these species were present at the time of occupation. These species could be represented in an anthracological study of the charred wood remains which has either not yet been undertaken, or has not yet been published, but could also indicate a different ecology existed.

Hayonim Cave

Hayonim cave is located in Western Galilee, about 13 km inland from the coast (Bar-Yosef, 1991) (Figure 2.1). The archaeobotanical remains were studied by Maria Hopf (Hopf and Bar Yosef 1987). The modern vegetation is typical of the Mediterranean with *Quercus calliprinos*, *Pistacia palaestinia*, *Ceratonia siliqua* trees growing in the area, as well as wild stands of wheat and barley (Zohary 1973; Zohary *et al*. 2012; Rosen 1995). Hillman (1996) has also noted that, during the Natufian, the area was dominated by deciduous oak and *Pistacia atlantica* based on archaeobotanical and current ecological field surveys.

The Natufian occupation layers that are relevant here have been dated to 12,360 (+/-) 160 BP (Hopf and Bar Yosef 1987). Despite continuous excavations since 1965, systematic wet sieving and some flotation since 1968, it was only during the 1975 season that the excavators discovered any plant remains. Unfortunately, only three

edible taxa were found: wild barley, almond and possibly *Pisium* sp. (Table 4.7), and the total numbers of these remains were not recorded. Bar-Yosef and Hopf (1987) have interpreted these remains as being derived from human refuse and have noted that all of the species are indigenous to the area and therefore could have been collected locally.

Table 4.7. List of available data on taxa for Hayonim Cave from Bar-Yosef and Hopf (1987)

Plant name	**Plant part**	**Quantity**
Grasses and Cereals		
Hordeum spontaneum	partial grains	2
Other wild		
Amygdalus communis	nutshell frag.	? From 3 samples
cf. *Pisum* sp.	corroded seeds	? From 3 samples
Lupins pilosus	fragmented seeds	? 15? Samples

4.5. Limited regional conclusions

The above data suggest that inhabitants of these sites took advantage of locally available plant resources, which may have changed seasonally and with longer term environmental changes. However, the general nature of the conclusions that can be reached based on the data from these five Southern Levantine sites highlights the need for more Epipalaeolithic excavations, and importantly, more systematic archaeobotanical sampling. Despite the low number of sites with archaeobotanical finds and the low taxonomic diversity of what is found, the Epipalaeolithic sites described here demonstrate that integrated large scale sampling and flotation does result in the discovery of identifiable plant remains. This in turn allows us to examine the Epipalaeolithic with a higher resolution to understand the nature of the exploitable wild plant resources that were locally available. As noted in the introduction, one of the main aims of this thesis is to contribute new data which will allow us to begin addressing issues such as diachronic trends in plant use and management, helping to fill the gaps in our knowledge of early plant exploitation. The phytolith data and on-going charcoal analysis from Kharaneh IV is diminishing this dearth of knowledge and the material presented here will make considerable steps toward improving our understanding. Any and all future data will add greatly to the scope of interpretations we are able to make in order to better understand the hunter-gatherers, their environments, diets, activities and society.

Chapter 5. Archaeobotanical Methodology

Here I present the methods used to recover, assess, analyse, and contextualize the archaeobotanical macro-remains (excluding charcoal) made available to me from the 2008–2010 excavation seasons at Kharaneh IV. The methods described here have been developed to address the research questions I have laid out in my Introduction (Chapter 1).

5.1. Field methods: sampling and flotation

Using an initial sampling strategy established by Sue Colledge in 2008, 10 L flotation samples were collected from all undisturbed deposits for flotation. All loci with a total volume of less than 10 L were 100% collected and sent for flotation. In 2009, in order to increase the retrieval rate of small artefacts and biological remains, the sampling strategy was expanded to 100% flotation for all undisturbed deposits, regardless of volume. Flotation was conducted in one of Gordon Hillman's original flotation tank machines, which was based on French's Ankara type machine (French, 1971). The fine flots were collected in flotation bags designed by Sue Colledge, which were made in the town of Azraq by local women and had an aperture of 250 μm (Figure 5.1). The fine flots were hung to air dry in the shade.



Figure 5.1. Fine flots drying in the shade in Azraq. Photo credit: Elizabeth Stroud

5.2. Selection of samples

A selection of floated soil samples were prioritised for zooarchaeological (Louise Martin, Jennifer Jones) and anthracological (Eleni Asouti) study and exported to the University of California, Berkeley under the care of Lisa Maher. Subsequently, of these samples, 95 unique trench/loci samples were redistributed to me at the archaeobotany lab of the University of Nottingham (Figure 5.2). All necessary permits were obtained for the study and export of the material from the Director General, Department of Antiquities of Jordan: Dates 2009; Ref No. 12-5-2404; 2010 Ref No. 12-5-3258. Here I present the results for these 95 samples from the 2009 and 2010 field seasons. The heavy residues were not provided for analysis.

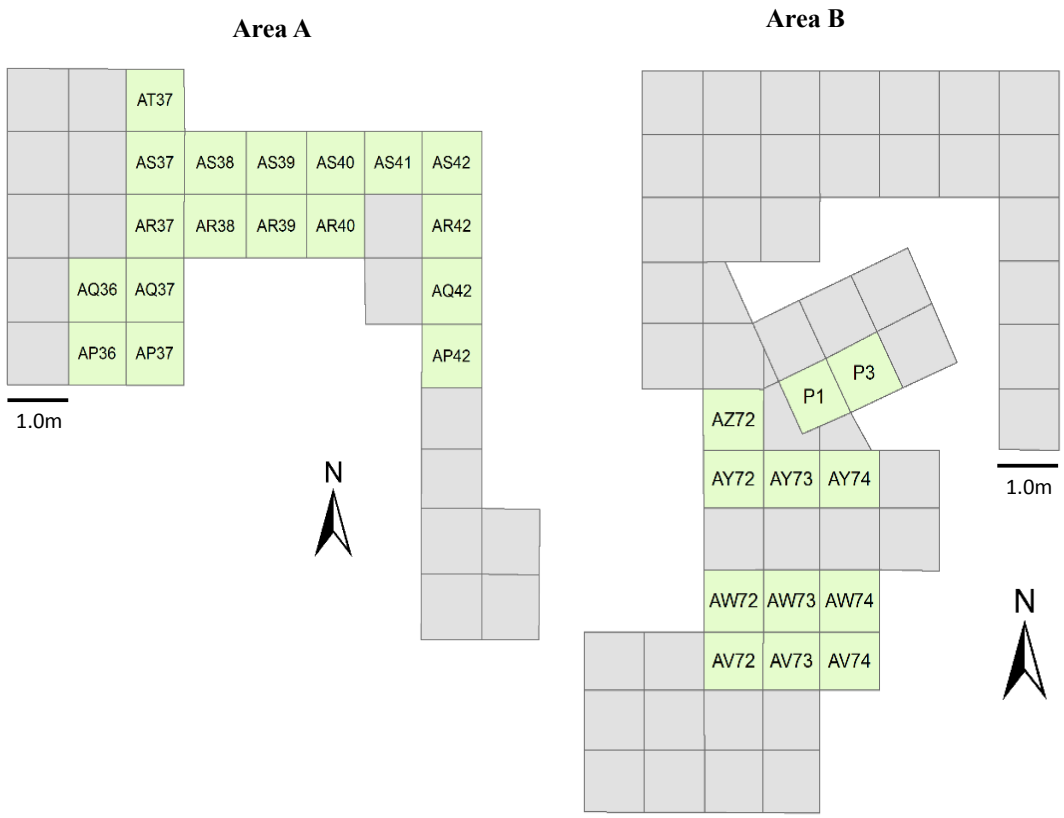


Figure 5.2. Spatial distribution of sampled squares in Areas A and B.

5.3. Types of archaeological contexts

The samples studied and analysed here originate from a variety of contexts/loci, such as occupation surfaces, hearths, deposits, floors and potential middens (see Table 5.1 for Area A and Table 5.2 for Area B for lists that include descriptions of the types of loci/contexts covered and their locations). Descriptions of the unit types/loci

classifications were based on the archaeological interpretation of the loci/deposits made by the excavators in the field. In total, 41 samples from Area A, representing 14 unique Loci, and spatially 17 unique squares are presented here. For Area B, 54 samples from 42 unique Loci, and spatially 12 unique squares are analysed.

Table 5.1. Loci descriptions and squares for Area A

Area	Description	Loci	Number Samples	Present in Square																
				AP36	AP37	AP42	AQ36	AQ37	AQ42	AR37	AR38	AR39	AR42	AS37	AS38	AS39	AS40	AS41	AS42	AT37
A	Occupation surface	003	8						X			X		X	X	X		X	X	X
A	Occupation surface	004	6						X				X		X	X		X	X	
A	Occupation surface	008	9			X					X		X	X	X	X	X	X	X	
A	Hearth	034	2											X						X
A	Sediment beside hearth	035	4		X			X		X				X						
A	Compact sediment	041	3	X				X										X		
A	Dark brown stained area	046	1	X																
A	Dark spot	049	1	X																
A	Dark Spot	050	1	X																
A	Deposit	057	1	X																
A	Hearth	065	1	X																
A	Hearth	067	1				X													
A	Compact floor beside hearth	076	2		X										X					
A	Compact sediment cut by hearth 67	084	1	X																
		Total:	**41**	**7**	**2**	**1**	**1**	**2**	**2**	**1**	**1**	**1**	**2**	**4**	**4**	**3**	**1**	**4**	**3**	**2**

Table 5.2. Loci descriptions and squares for Area B

Area	Description	Loci	Number of Samples	Present in Square												
				R/S2/60.P1	R/S2/60.P3	AW73	AZ72	AV72	AV73	AV74	AW72	AW74	AY72	AY73	AY74	
B	Deposit	027	2	X	X											
B	Deposit	028	1	X												
B	Alternating occupation surfaces and refuse. Midden?	030	1	X												
B	Deposit	031	1	X												
B	Alternating occupation surfaces and refuse. Midden?	032	1	X												
B	Dark-brown rich organic sediment	002	3		X	X	X									
B	Mid grey sediment	004	1		X											
B	Occupation surface	005	1		X											
B	Deposit	006	1		X											
B	Deposit	009	1		X											
B	Deposit	034	1		X											
B	Deposit	061	1		X											
B	Light Grey silty deposit	090	1		X											
B	Mid brown clayey silt	091	1		X											
B	Whiteish sediment	099	1		X											
B	Sediment/Deposit - mid brown	102	1		X											
B	Dark Brown Deposit	104	1		X											
B	"Burnt area"	108	1		X											
B	Light Grey deposit	110	1		X											
B	Light brown bone concentration	115	1		X											
B	Compact with white clay	124	1		X											
B	Loose bone layer in orange clay	128	1		X											
B	Ashy charcoal and bone concentration	139	1		X											
B	Bone layer "big"	140	1		X											
B	Loose grey ashy deposit	151	1		X											
B	Sterile clay	156	1		X											
B	Light Grey silt deposit	073	2					X			X					
B	Mid grey deposit	074	2						X		X					
B	Mid Brown deposit	086	3			X			X			X				
B	Dark Deposit	137	1						X							
B	Loose sandy deposit	141	2						X	X						
B	Bone layer	088	1							X						
B	Soft loose bone layer	127	1							X						
B	Compact deposit with burnt lithics	087	2			X					X					
B	Loose sandy deposit	149	1								X					
B	Very dark brown deposit/fill	081	1			X										
B	Very dark brown to black hearth fill	082	1			X										
B	Loose brown deposit beneath scatter 095	130	1			X										
B	Occupation surface	040	2				X						X			
B	Deposit	041	3										X	X	X	
B	Dark Deposit	114	1										X			
B	Deposit	036	1				X									
		Total:	**54**	**5**	**22**	**6**	**3**	**1**	**4**	**3**	**4**	**1**	**3**	**1**	**1**	

5.4. Sample processing and sorting

At our labs in Nottingham, flots large enough to be sieved into two fractions for better sorting were divided into two (<1mm, and 0.3mm fractions) using geological sieves.

Due to the often-poor washes and the very finely grained, silty nature of some of the flots, I used a <0.2mm sieve to remove as much of the sand/soil that was obscuring my assessments under the microscope as possible. A very few "Large" (>~100ml) and particularly fine samples were divided in two using a riffle-box in order to create a random subsample. For these, the subsample (1/2) was then sieved into 1mm and 0.3mm fractions and fully sorted. In the interest of time efficiency, if any seeds were found during the sorting of the subsample, then the entire sample was fully sorted and in cases where no seeds were found in the subsample, the second half was briefly scanned and it was assumed that no seeds were present in the sample. Very small samples (generally under ~5ml) were sorted in their entirety with no additional division. Under the aforementioned protocol, all seeds, burned masses, fruit/nut shell fragments and unidentifiable items (excluding charcoal) were sorted under a low-power (x7-45) stereoscopic binocular microscope and extracted for quantification, identification and further investigation.

5.5. Identification

Initially, I amalgamated unknown taxa into provisional genus/species (sometimes descriptive) groups. I then re-examined and compared these to each other and regrouped accordingly. I created a standardised seed recording form (Appendix 1), which I used to make initial lab sketches and take measurements (See: Appendix 3: Seed Catalogue) of all types and groups of seeds that I identified as unique. To further enhance these preliminary identifications to plant family, genus or species level, I consulted reference material from the University of Nottingham's collection and identification criteria from a variety of more general atlases such as Berggren (1968, 1981), Cappers *et al.* (2006), Nesbitt (2006) and online resources such as Willcox's (www.g.willcox.pagesperso-orange.fr,) and Danin's online version of the Flora of Israel (http://flora.org.il/) before visiting other reference collections and cross-checking material with other archaeobotanists.

I made multiple visits (in 2014–2016) to the reference collection at University College London (UCL), where I consulted the modern and charred Near Eastern collections as well as the Hillman collection of archaeobotanical material from the Abu Huyera site (see Moore *et al.* 2000). There, I also worked closely with Sue Colledge on furthering many of my identifications as well as consulting Gordon Hillman's personal

(unpublished) field notes from his fieldwork in the Azraq Basin during the 1980s and 1990s. In 2015, I made a brief visit to the University of Sheffield where Prof. Glynis Jones kindly provided access to the reference collection of the Department of Archaeology of mostly modern material.

In November of 2015, I travelled to Bar Illan University, Israel, where I spent a week consulting their extensive Near Eastern seed collection, and was able to examine some of the highly comparable Ohalo II material. While in Israel, I met with with Dr. Yoel Malmud and Prof. Ehud Weiss. Unfortunately, I was only able to bring photos, drawings and notes of my seeds to Israel, however, I had sufficient time to examine, and sketch many of the likely species candidates in their collection and further narrow many of my identifications.

In the Spring of 2015, I also met with Dr. Mark Nesbitt at Kew Gardens to discuss the varieties of wild grasses (Gramineae) found at Kharaneh. Due to low diversity and numbers of the Gramineae I divided these into 3 categories according to size: Large (>1.5mm), Medium (1-1.5mm) and small (<1.0mm). Though there are few of these (particularly the Medium Graminae), there is potential for further identification. However, the time frame and the scope of this PhD did not allow continuation of work in this direction.

Identifying the plant remains at Kharaneh was the primary goal of my study since species' ecological requirements and growth habits are sensitive to environmental fluctuation, specifically water stress. Indet. (Indeterminate) and *cf.* identifications were given to remains that did not correspond to all of the identification criteria due to a lack of diagnostic features, distortion from charring or poor preservation, or if they presented characteristics of more than one taxa. Following identification, all results were recorded in the Master Data Tables (Appendix 2). Nomenclature follows the *Flora of Turkey* (vol. 1-11 Davis *et al.* 1965-1988) wherever possible. Where different nomenclature was used, the flora is listed.

5.6. The Kharaneh IV Seed Catalogue

I have compiled and created a detailed Seed Catalogue (Appendix 3) for all of the material found thus far at Kharaneh IV. The Seed Catalogue includes the following detail where available: Taxon, *Flora of Turkey* number, Common/Arabic name, measurements (length, breadth and width), physical description, notes on abundance and regional or temporally similar archaeological occurrences, geographical distribution, habitat and ecological data. Information was derived primarily from the *Flora of Turkey* (Davis *et al.* 1965-1988; Güner *et al.* 2001) and other sources of literature were used where appropriate to extract more information on ecological background (e.g. El-Esawi 1991, Ellenberg 1988), known (published) ethnographic use, and photos of the seeds. Descriptions include references to El-Esawi's (1991) vegetation record of Jordan and Nelson (1973)'s account of the Azraq Desert Oasis vegetation, which built on historical botanical mentions and accounts of local vegetation from the Azraq basin.

5.7. Seed Photography

The photographs included in the Seed Catalogue (Appendix 3), were taken in the archaeobotanical laboratory in the Department of Archaeology at the University of Oxford directed by Prof. Amy Bogaard in May 2016 using Image Pro Insight 65. Scale bars have been included in the images.

5.8. Creating the Kharaneh IV Reference Collection

The species selected and presented in the Seed Catalogue (Appendix 3) represent the taxa included in the reference collection I have created for Kharaneh IV. This material is available for observation upon request and is currently being stored in the Archaeobotanical Laboratories in the Department of Archaeology at the University of Nottingham.

5.9. Quantification

As much of the material studied here was fragmented or distorted, I have adapted the method proposed by Jones (1991) to quantify cereals and wild grasses, and thus include all wild and pre-agricultural seeds in order to best detail and describe all of the rare Epipalaeolithic material present at Kharaneh IV, while ensuring the same items were only counted once by cross checking the assemblage as a whole for different

taxa. Due to the paucity of material and the uniqueness of each individual seed, I have counted all Gramineae fragments as *c.*1, as we are dealing with so few individuals, and each individual fragment is clearly from a single seed where no matching fragments are present within the sample. The transversal apical/embryo end, longitudinal-ventral part end of each seed were counted and where absent, the number of seeds were carefully identified and estimated from the fragments consisting of more than half of the seed. All whole and fragmented (where fragments represent a separate seed) seeds were counted, as well as indeterminate remains. Inner seed cores (where the testa has separated from the outer shell) were also counted. Indeterminate fragmented seeds were recorded as such, based on the observation of some distinctive features such as surface pattern, or a visible embryo. Clumps of burned masses were measured by fragments due to their small size and rarity. All were ~1mm. Items in the fruit/nut category were very small and had no diagnostic features, and were thus not identified beyond being placed in this category and were counted based on number of fragments.

5.10. Amalgamation of loci data for spatial and diachronic analysis

Individual samples (originally called bags by the excavation team) from the same locus and square were grouped together in order to ensure that the samples represented individual events/time periods (Jones 1991). Justified by the archaeological stratigraphy and the directors'/excavators' interpretations of the loci, samples from squares with identical loci have been a) examined at the spatial level (same loci, different squares), to identify any areas of concentrations which may reflect differing area use, and b) combined to examine temporal (and possibly cultural) relationships through the analysis of changes/variation relative to other loci located above, below and throughout the stratigraphy. Squares and loci were assigned by the excavators.

Stratigraphic Zones

As the final and updated Harris Matrix for the site and sequence of stratigraphic layers (Loci) was unavailable, I devised the stratigraphic zone classifications using a combination of the available information from the existing versions of matrices, the excavators hand written field notes (where available), combined with the known, published sequences (Maher *et al.* 2012) and radiocarbon dates from Richter *et al.*

(2013) to place the samples into chronological groups, which I have called stratigraphic zones. These are detailed in Figure 5.3.

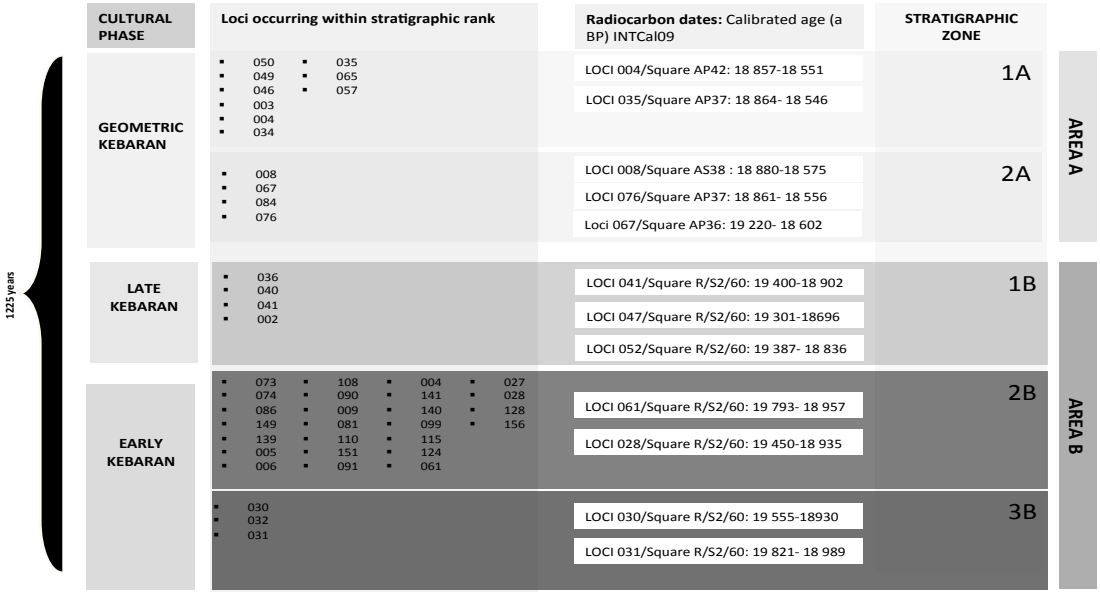


Figure 5.3. Stratigraphic Zones, associated loci and radiocarbon dates for Areas A and B. Dates from Richter *et al.* (2013).

5.11. Archaeobotanical data analysis

Summary statistics

I produced a range of statistical summaries of the data, focusing on the abundance, density and diversity of material in squares, loci, areas (A or B), and stratigraphic zones. I focus on the spatial and temporal distribution of overall seed density, as well as changes in the taxonomic composition of assemblages from areas and stratigraphic zones as a proxy for temporal change. Items that had been measured by volume, such as tuber-like fragments and burned masses, are considered separately.

Due to the rare nature of the archaeobotanical material presented here, all items have been included wherever possible. For example, the mineralized *Lithospermum sp*. and the Compositae Kernel type items have been included in the overall data (simple stats such as range of species, densities and change over time. Where necessary, the potential obscuring of the results by the presence of these items is discussed and results are presented with these items included and removed. However, due to the

nature of the information presented, their inclusion provides useful additional information.

Density

I first focus on the distribution of samples among squares and loci. I then quantify the abundance and distribution of seeds and fragments among squares and loci, including maps of seed abundance in individual areas and stratigraphic zones. I next carry out similar analyses on seed/fragment density. Density was calculated by dividing the total number of plant items by the litres of soil in a sample. While every effort was made to locate the volume of soil of each sample, the excavators have stated that, for six samples from Area A, this information was either accidentally not recorded or has been lost. To account for this, all samples without a recorded volume have been removed from all analysis that required any density measures. The density measure allows the highlighting of trends across areas and stratigraphic zones while accounting for differences in sampling effort (soil volume), which could confound comparisons of raw abundances.

Next, I focus on variation in abundances and densities of individual taxa for each area and stratigraphic zone in order to identify changes in the abundance/density of seeds through time. Density was calculated as above by dividing abundances by soil volume. I also calculate measures of relative density. Relative density was calculated by dividing the density of a taxon in a particular area (or stratigraphic zone) by the sum of all taxon densities from that area (or zone). This measures allows changes in the relative abundance, or dominance, of taxa between zones or areas to be analysed while accounting for changes in the total density of seeds.

Diversity and rarefaction

I calculate two measures of diversity for areas and stratigraphic zones, following the procedures for density outlined above. The first is simply the number of taxa present in an area or stratigraphic zone. The second, which I refer to as ‘taxa density’ divides the number of taxa by the volume of soil extracted and thus accounts for differences in soil volume that may confound comparisons since larger areas or volumes will tend to contain more species (Rosenzweig 1995). I compare diversity measures across areas and stratigraphic zones.

The taxa density measure accounts for differences in the amount of soil but not for the number of seeds in a sample/area/zone. This could obscure results because the number of taxa is expected to increase with the number of seeds, especially at small sample sizes (Hurlbert 1971; Gotelli and Colwell 2001). Because of this, I carry out rarefaction analysis, a technique common in community ecology (see: Heck *et al.* 1975; Lepofsky and Lertzman 2005; Gotelli and Colwell 2001) by generating rarefaction curves for Areas A and B and for stratigraphic zones. These curves demonstrate how taxa richness accumulates with increasing sample size (number of seeds), allowing for comparisons at a single sample size. Rarefaction curves are generated by randomly re-sampling the pool of samples (seeds in this case) multiple times and then plotting the average number of taxa found in each sub-sample of a particular size. Initially the curve should grow rapidly, as the common species are found, but then the curve will plateau as only the rarest species remain to be sampled (see Gotelli and Colwell 2001). By examining the final slope of the curve, I can also determine if there are likely to be undiscovered species present in an area or zone. Rarefaction curves were created using the 'vegan' package (Oksanen *et al.* 2017) in R v.3.3.2 (R Core Team 2017)

Correspondence analysis (CA)

I used the multivariate exploratory technique of correspondence analysis to investigate variation among botanical composition of the samples and the stratigraphic zones. The primary aim of using CA was to identify major trends in taxonomic similarity in the dataset (e.g. Lange 1990; Shennan 1997; Colledge 2001; Baxter 2003; Bogaard 2004). I used R v. 3.3.2 (R Core Team) to run the analysis and plot the results graphically. I have applied CA to all of the taxa present at Kharaneh IV in order to explore the major trends and variation resulting in diachronic ecological change throughout the stratigraphic zones. The plots presented here show the distribution of my sample data points and reveal trends in the sample composition and their variation. The distances between the samples shows the level of their compositional similarity (e.g. close samples are more similar in terms of the taxa they contain) and therefore, samples that are clustered together are more similar that those at the opposite end of the axis. Similarly, species that fall close together on plots tend to covary positively in samples.

I also carry out an additional correspondence analysis after grouping taxa into families (following the *Flora of Turkey*). In the initial correspondence analysis, seeds were classified to different taxonomic levels (species, genus or family), and included many listed as 'cf.'. Reclassifying to family removed this inconsistency in taxonomic resolution and also removed uncertainty in the relationship between identified taxa and 'cf.' classified seeds.

Habitat (wet-dry) preference and abundance

Using an autoecological approach (Jones 2002), I carried out an analysis to determine whether the concentration of taxa with different habitat preferences varied among areas and stratigraphic zones. Such changes may be indicative of environmental change. Using information on habitat and growing conditions from the *Flora of Turkey* (Davis *et al*. 1965-1988; Guner *et al.* 2001) and other sources (Ellenburg 1988; Dallwitz 1980; Grime, 2006) I classified taxa as having 'wet' or 'dry' or 'varied' (generalist) habitat preferences (see Appendix 3 for individual taxa preferences). While admittedly coarse, finer classifications were not possible due to limitations on the taxonomic resolution to which seeds could be identified. After classification, I plotted the seed density and taxa density of 'wet', 'dry' and 'varied' taxa across regions and stratigraphic zones and used chi-square (X^2) tests to determine if taxa and seed counts differ across areas or stratigraphic zones. Note that because X^2 tests work with proportions, differences in the total amount of soil or seeds between areas and/or zones do not confound these tests.

Chapter 6. Archaeobotanical Results from the Kharaneh IV Assemblage

6.1. Introduction

Here I present, explore and contextualize the archaeobotanical results. These data include descriptive information, such as number of individual taxa and loci descriptions, which have been extracted from the Master Data Tables (Appendix 2). These data provide the basis for the discussion and conclusions presented herein.

6.2. The master tables

Master Data Tables (Appendix 2) for both Area A and Area B have been created to present all of the primary raw data extracted from the material studied here. Both tables offer the following information: Area (either Area A or Area B); the square from which the sample originates; the locus from which the sample originates; the provided description of the locus; the stratigraphic zone from which the sample originates and the soil volume. In addition to these, the species/taxon or identification categorization is provided and, where possible, the family. The recorded plant part (e.g. seed) is also noted here.

6.3. Samples, squares and loci in Areas A and B

Table 6.1 outlines and highlights basic statistics extracted from the Master Data Tables. Here, the overall counts provide a general overview of the characteristics of the archaeobotanical material in Areas A and B. Of the 95 samples available for study, 41 were from Area A and 54 from Area B, with a total of 2985 seeds (1928 from Area A and 1057 from Area B) recovered from 3086.4 litres of soil, just under 1 seed per litre (0.96 seeds/L, 1.0 seeds per litre including unidentifiable seeds). Table 6.1 also shows the number of identified taxa/types, unidentifiable items, and fragmented items, along with the volume of burned masses/tuber-like fragments and the number of problematic samples (i.e. those with no available volume of soil).

Table 5.1 and Table 5.2 show, for Area A and Area B, how loci are distributed among squares and squares among loci, listing the basic descriptive aspects of the samples from each area. Samples from Area A were spread across 14 loci, from a range of

Table 6.1. Archaeobotanical overview statistics for Area A and Area B, followed by the two areas combined

Total of:	Area A	Area B	Combined Total
Samples	41	54	95
Volume (L) of soil assessed	1421.5	1664.85	3086.4
Samples with no identifiable seeds/plant parts	7	4	11
Number of identified taxa	31	44	46
Number of individual seeds identified	1928	1057	2985
Number of grass seeds identified	26	56	77
Number of unidentified seeds	64	32	9
Number of unidentified seed fragments	1117	1164	2281
volume(ml) of burned masses/tuber like fragments	7	25	32
Samples with no known volume of soil	6	0	6

contexts, including occupation surfaces, hearths, and surrounding areas. The number of loci within individual squares in Area A ranged from one to seven and many loci (003, 004, 008, 034, 035 and 041) were present in two or more squares, with Locus 008 containing the highest number of squares (nine; Figure 6.1). Half of the loci were found in just a single square (Figure 6.1). Of the squares sampled in Area A, there are many loci present in Square AP36 (seven loci), followed by AS37 (four loci). About half of the squares contained just a single locus (Figure 6.1).

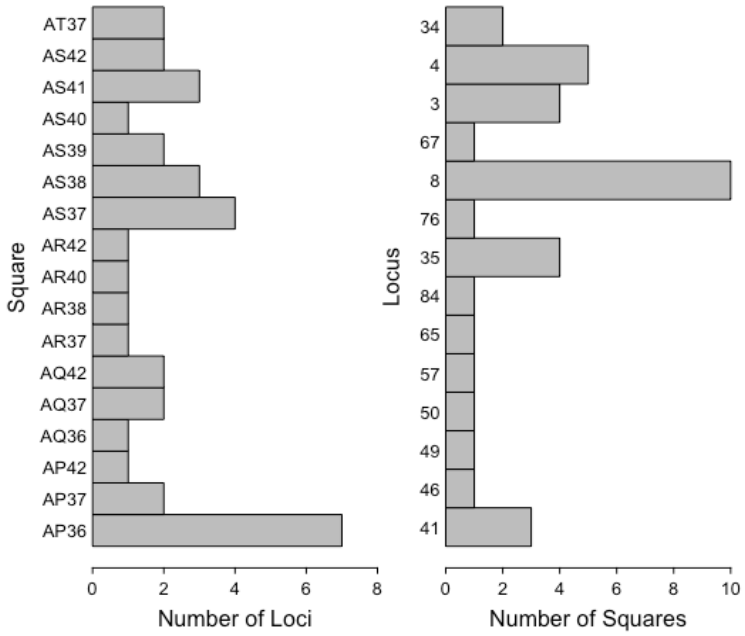


Figure 6.1. Number of loci per square (left) and number of squares per loci (right) in Area A

Samples from Area B were spread across many more loci (43 in total) and from a wider range of contexts than those from Area A (Table 5.2). Area B loci included occupation surfaces, possible middens, bone layers, lithics layers, and burnt layers (Table 5.2). Most loci were found in a single square, but ten crossed multiple squares, with Loci 002, 086, and 041 containing the most squares (Figure 6.2). Square 60.P3 contained by far the most loci (>20). AW73 was next with five loci, and only four squares had just a single locus (AY74, AY73, AW74 and AV72, Table 5.2 and Figure 6.2) providing us with relatively broad coverage.

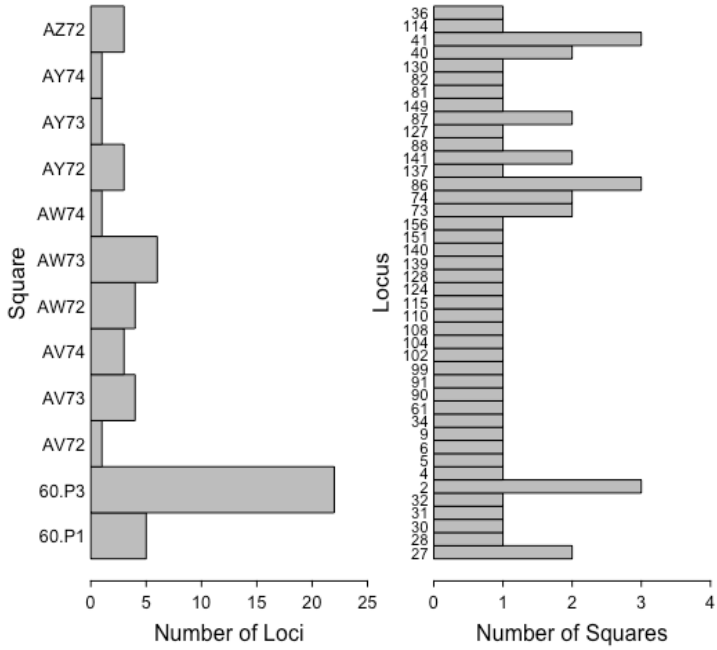


Figure 6.2. Number of loci per square (left) and number of squares per loci (right) in Area B.

Figure 5.2 shows a map of the complete distribution of sampled squares from both areas studied here. There is a broader distribution of samples in Area A, from a wider range of squares, despite there being more loci excavated in Area B. The squares sampled from Area B are predominantly from the central part of the excavated area, but their distribution is still patchier than for Area A.

Figure 6.3 shows a map of the sample distribution by stratigraphic zone for A1 and A2. There are samples from both stratigraphic zones for seven squares. Squares unique to A1 were AT37, AR37, AQ37, AS39 and AQ42. Squares unique to A2

included AQ36, AR38, AS40, AR40, and AP42. Squares common to both time periods were scattered across the entire area and were interspersed with those unique to a single stratigraphic zone.

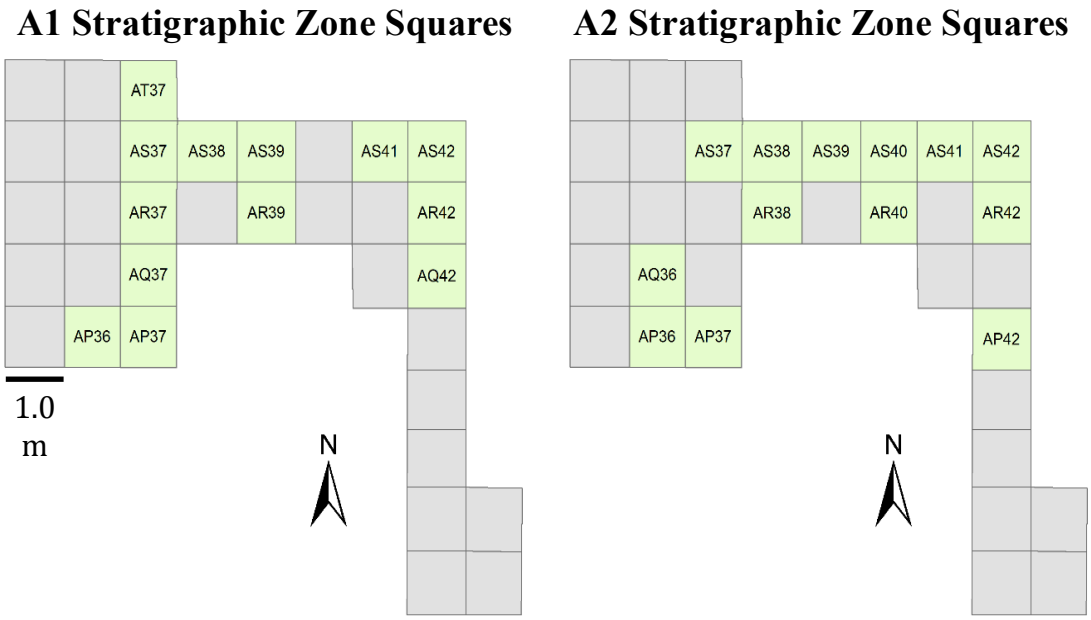


Figure 6.3. Squares with samples from stratigraphic zones in Area A.

Figure 6.4 shows a map of the sample distribution by stratigraphic zone for B1, B2 and B3. The pattern of sampling across stratigraphic zone differs from the spatial interspersion of Area A. In Area B, each stratigraphic zone covered a different pattern of squares, almost spatially distinct from those in other zones. No squares contain a sequence of samples spanning all three zones. However, the neighbouring squares P1 and P3 between them offer coverage through all stratigraphic zones. Additionally, square AW73 is present in both B1 and B2, but not B3.

6.4. Distribution of seed abundance

Seed abundance by area

Figure 6.5 shows the total abundance of seeds that have been found at Kharaneh IV in both Areas A and B. The purpose of this figure is to draw a general picture, at the most basic level, of the range of species, and their abundances, present at Kharaneh IV throughout the entire occupation of the site, regardless of where the seeds originate and to make my findings comparable with other coeval sites discussed herein (see

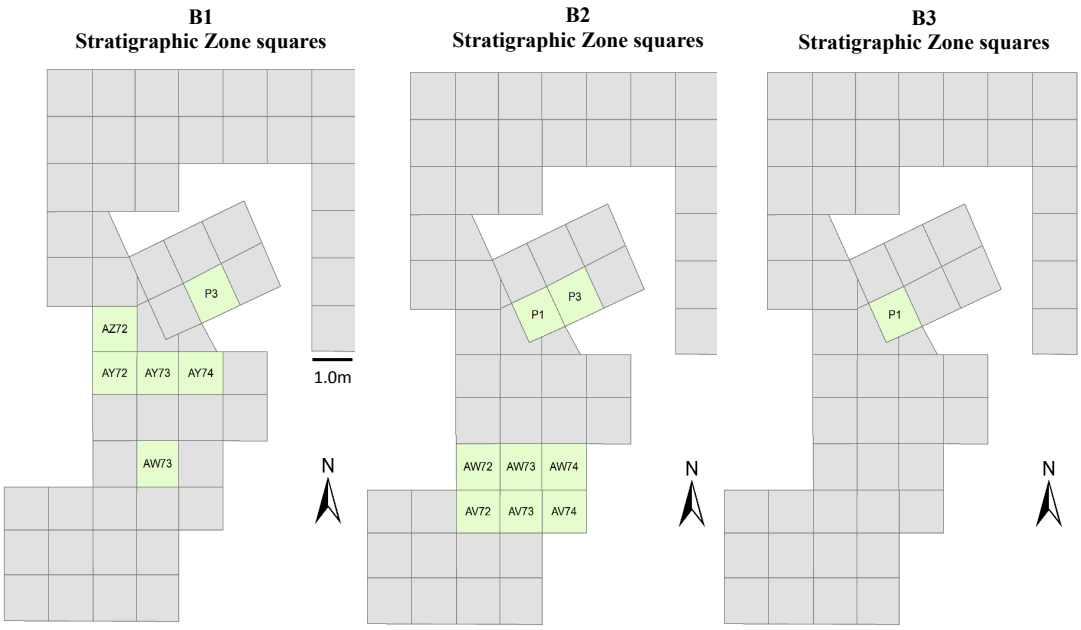


Figure 6.4. Squares with samples from stratigraphic zones in Area B.

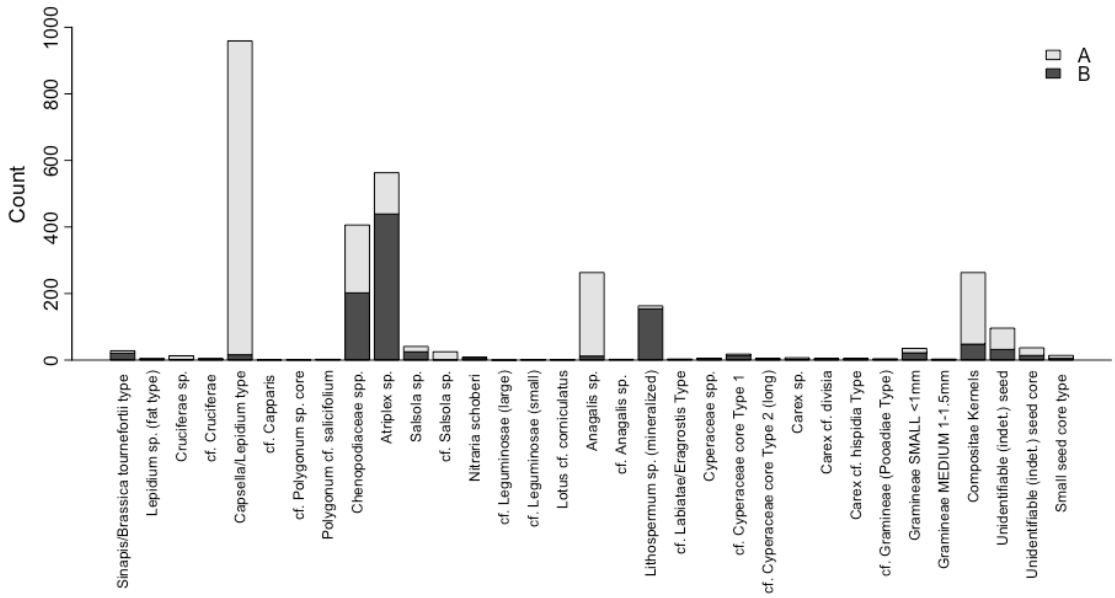


Figure 6.5. Total seed abundance for Kharaneh IV. All samples included from both Area A and Area B (using MNI)

Chapter 4). A key pattern that emerges is that the assemblage is dominated by a handful of abundant taxa, while most taxa are rare, but these dominant taxa are not necessarily the same in both areas. The dominant species are *Capsella/Lepidium* which we can see are primarily located in Area A. Following this there are many *Atriplex* sp. which primarily originate from Area B. Next, there are a rather even

distribution of Chenopodiaceae spp. spread between both Areas A and B, followed by *Anagalis* sp. (mostly in Area A), Compositae kernels (mostly in Area A) and finally the mineralized *Lithospermum* sp. which were mostly in Area B.

Figure 6.6 show the spatial distribution of seeds in Area A and Area B, without correcting for the volume of excavated soil. Seed number from Area A were primarily concentrated in the western squares (AQ36 and AP36), while in Area B, high relative numbers of seeds were found scattered across the sampled squares. Overall, more seeds were recovered from squares in Area A than from squares in Area B.

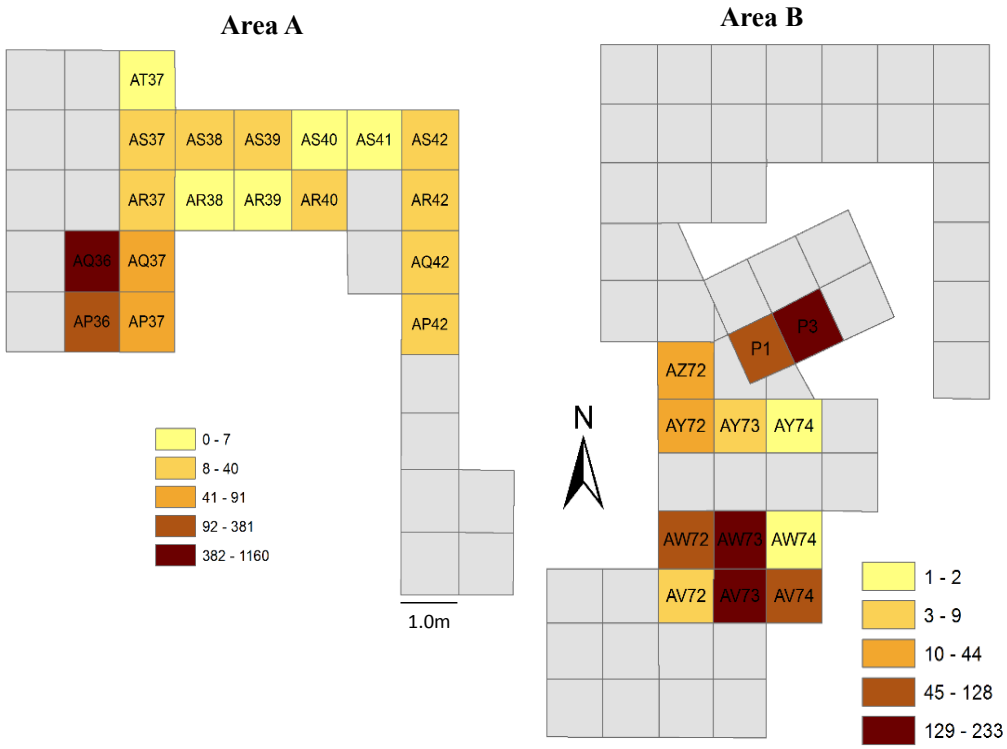


Figure 6.6. Spatial distribution of seeds in Areas A (left) and B (right) with no correction for volume.

Seed abundance by stratigraphic zone

Figure 6.7 shows the spatial distribution of seed abundance in stratigraphic zones A1 and A2. While not identical, the dominant pattern of higher seed abundance in the south-western squares is similar in both zones. Square AP36 has relatively high seed abundance in both stratigraphic zones, though it is highest in A1. AP37 has relatively high abundance in A2, but lower abundance in A1. AQ37 and AQ36 are only present in A1 and A2 respectively and both have high seed abundance. Figure 6.8 shows the

spatial distribution of abundance in stratigraphic zones within Area B. The highest seed abundances were found in samples corresponding to B2, with particularly high abundance (though still lower than most squares in Zone A) were P3, AW72, and AW73 which were split between the northern and southern parts of the central area. Seed abundances in P3 and AW73 were lower than in B2, as was the seed abundance in the sole square in B3 (P1), relative to P1 in zone B2.

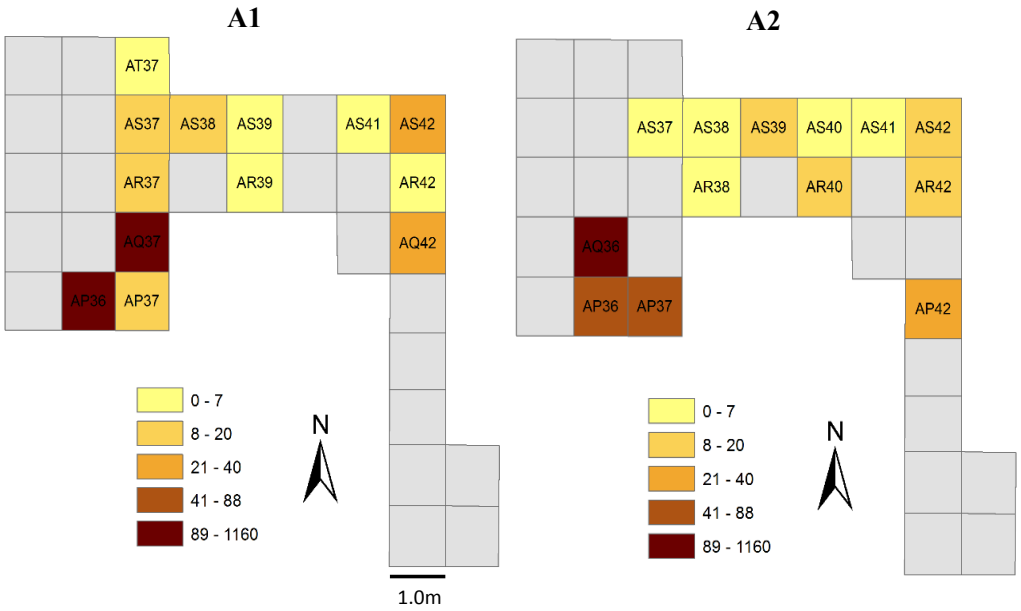


Figure 6.7. Spatial distribution of seed abundance in stratigraphic zone A1 (left) and A2 (right). Zone A1 is nearest the surface.

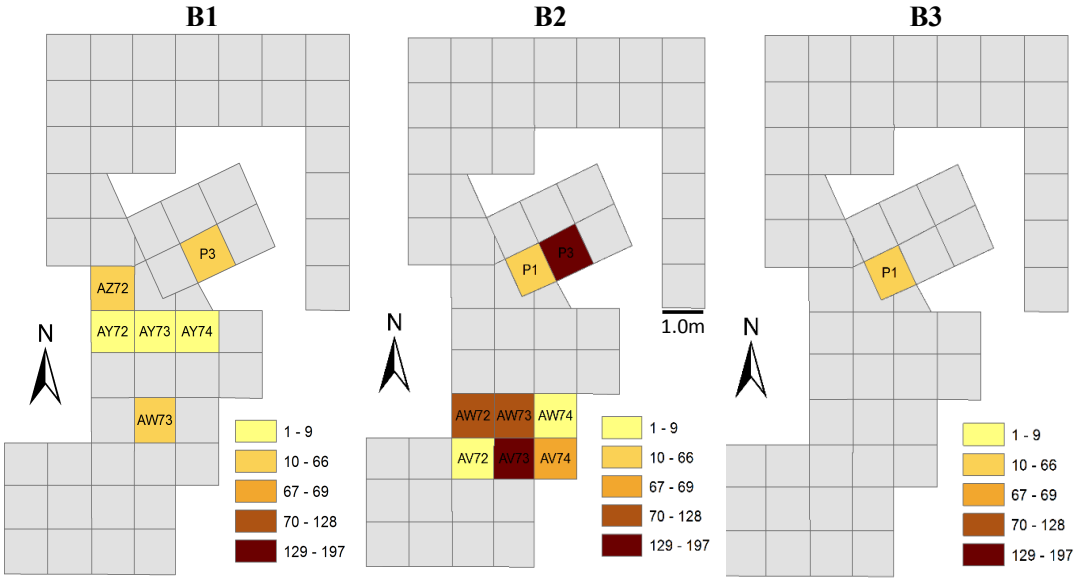


Figure 6.8. Spatial distribution of seed abundance in stratigraphic zone B1 (left), B2 (centre), and B3 (right). Zone B1 is nearest the surface.

6.5. Burned mass and tuber-like fragments' volumes

Figure 6.9 displays the total volume of fragments for burned masses and tuber-like fragments found at Kharaneh IV in both Area A and Area B. Here we clearly see that there are more burned masses and more tuber-like fragments in Area B, these were all of approximately the same size and volume. There were no detectable fragments of tuber present in Area A, but some burned mass fragments were found. With a total volume of under 30ml of Burned Masses and less than 5ml of Tuber like fragments, for the entire assemblage of studies samples no further analysis was undertaken as part of this study.

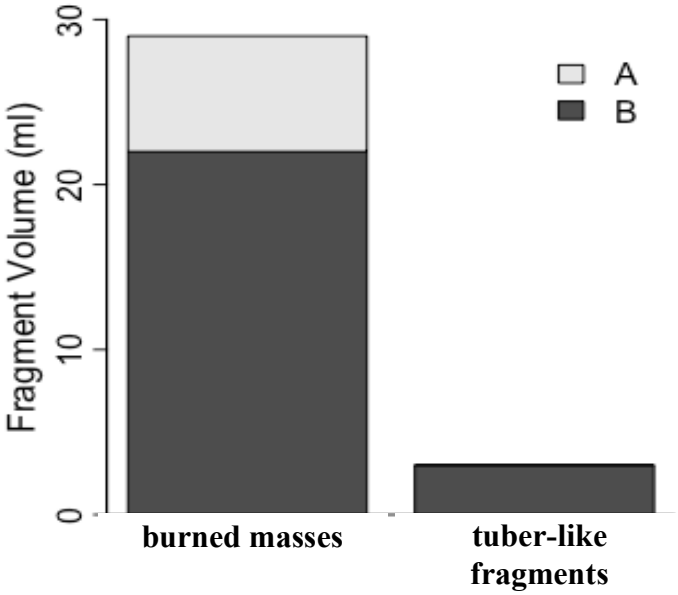


Figure 6.9. Total volume of fragments of burned masses and tuber-like fragments found at Kharaneh IV in Areas A and B.

6.6. Grass Seeds (Gramineae)

Table 6.2 offers a brief overview of the range of Gramineae found at Kharaneh IV thus far, as well as a breakdown of which area they originated from. The majority of the records here represent broken seeds (noted in Table 6.2) and, due to their low numbers, were not included in many of the analysis. This table allows us to examine this category on its own and highlight the presence of the 77 individual occurrences of grass onsite.

Table 6.2. Grass seeds (Gramineae) recovered at Kharaneh IV. See Seed Catalogue (Appendix 3) and Archaeobotanical Methodology (Chapter 5) for further details and identification criteria

Taxon	Family (FoT)	Plant Part	Area A	Area B	Total
cf. Gramineae (Pooadiae Type)	Gramineae	seed	0	3	3
Gramineae SMALL <1mm	Gramineae	seed	13	22	35
Gramineae SMALL	Gramineae	broken seed	3	3	6
Gramineae MEDIUM 1-1.5mm	Gramineae	seed	2	1	3
Gramineae MEDIUM	Gramineae	broken seed	1	8	9
Gramineae LARGE >1.5mm	Gramineae	broken seed	1	6	7
cf. Taeniatherum sp.	Gramineae	broken seed	0	1	1
***Hordeum* sp.**	Gramineae	broken seed	1	12	13
		Totals	**21**	**56**	**77**

6.7. Archaeobotanical density at Kharaneh IV

The above results focused on the raw abundance of seeds from Kharaneh IV, disregarding differences in the volume of soil extracted for each sample. Below, I account for difference in soil volume between samples, stratigraphic zones and areas by calculating seed density (seeds per L of soil). Controlling for the volume of soil extracted allows for more in depth and meaningful comparisons of spatial and temporal patterns.

Density by square and locus

Figure 6.10 displays the densities by square for Area A with an axis break (in order to keep the scale within reason, whilst still demonstrating the highest densities). This figure takes into account only the density of seeds, seed fragments or burned masses/tubers (ml) respectively and their square of origin. It does not account for the stratigraphic layer/locus. Figure 6.10 demonstrates those squares that provided the highest density of material and differences in the type of material preserved. In the densest squares, AQ36 and AP42, the evidence suggests a trend across all item types.

AP36 also has a comparatively high density of seeds and seed fragments, however it has an absence of burned mass/tuber-like fragments.

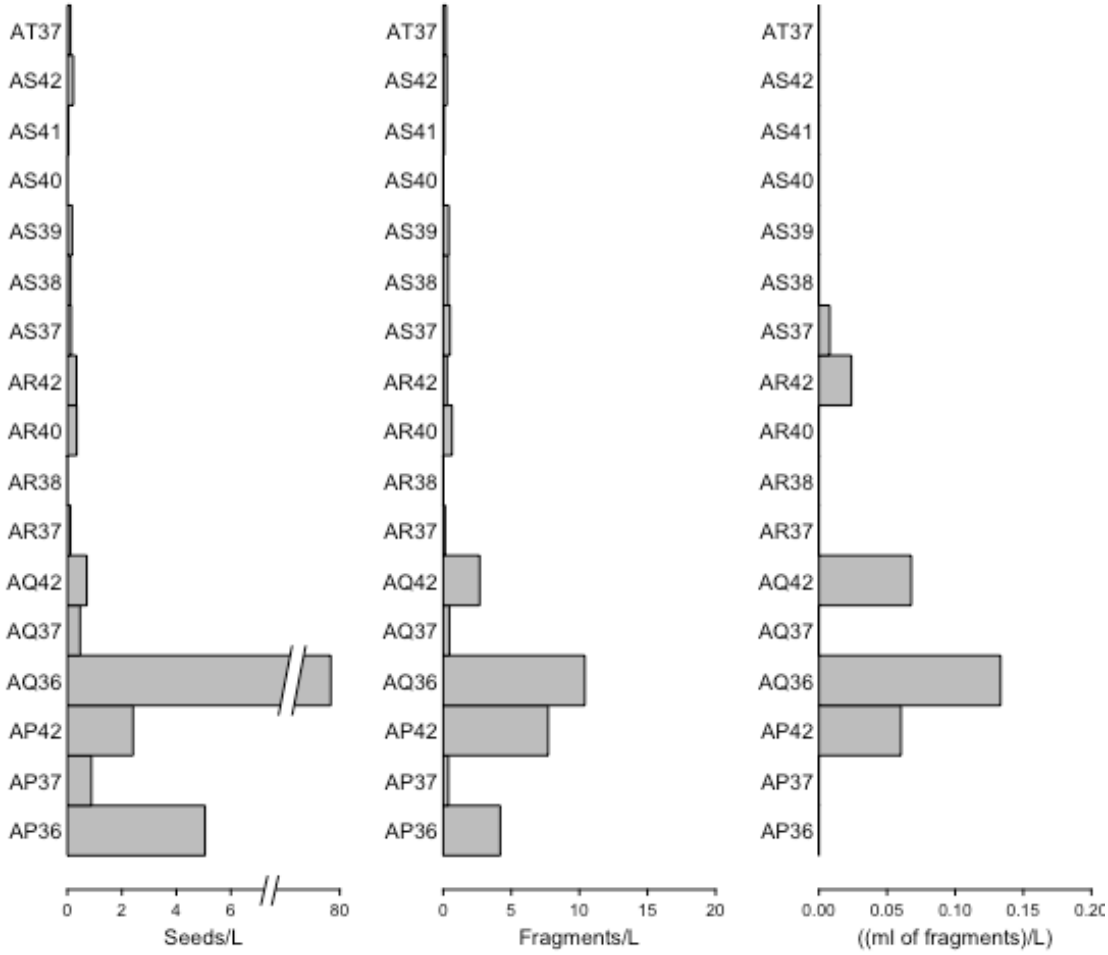


Figure 6.10. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in squares from Area A. Note the axis break for square AQ36 in the seed density plot.

Figure 6.11 shows density of item type and locus for Area B. The purpose of this figure is to demonstrate which loci had the highest densities. This figure is particularly useful in pinpointing particular layers/periods with intensive use. Here the evidence suggests that the highest densities (in this case I have considered 4 or more seeds/L of soil as 'high') across all three item types are found in loci 81 (Very dark brown deposit/fill), 5 (Occupation surface), 108 (Burnt area) and 141 (Loose sandy deposit).

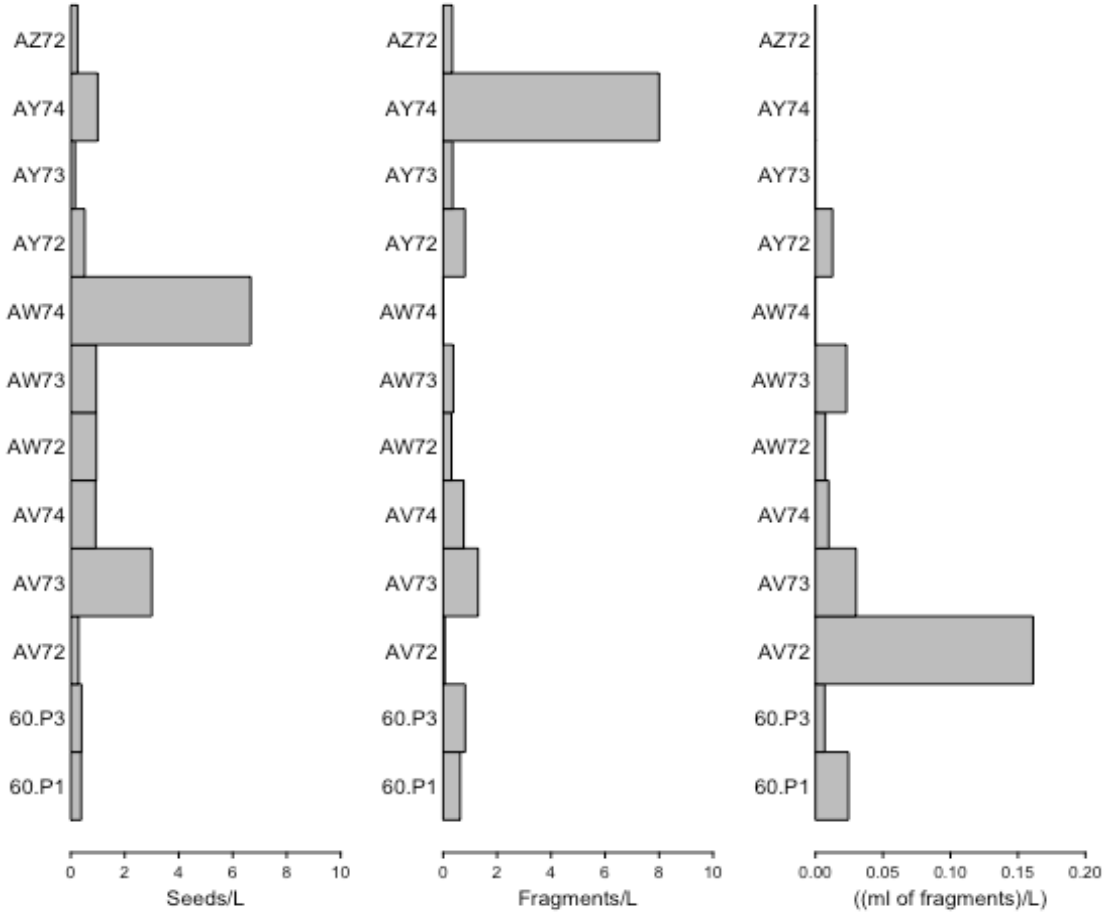


Figure 6.11. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in squares from Area B.

Figure 6.12 and Figure 6.13 show densities by locus for Areas A and B, respectively, in contrast to Figure 6.10 and Figure 6.11, which showed density by square. The overall density of seeds is higher in Area A vs. Area B, as there are 4 loci with densities of more than 20 seeds/L.

Some highlights from Area A are: Locus 67 (Hearth) has the highest density of seeds as well as burned mass/tuber-like fragments. Following this, Loci 49 (Dark spot) has a high density of seed fragments as well as seeds. Loci 65 (Hearth) and 84 (Cut by hearth) also both have high density of seeds and seed fragments. In Area B (Figure 6.13), fragments were relatively abundant in AY74, but seeds were not as abundant. Also, in AW74 there is a relatively high density of seeds, however, there are no seed fragments and no burned masses/tuber-like fragments. Alternatively the evidence suggests the highest concentration of burned masses/tuber-like fragments present in AV72, while there are comparatively few seeds and fragments present.

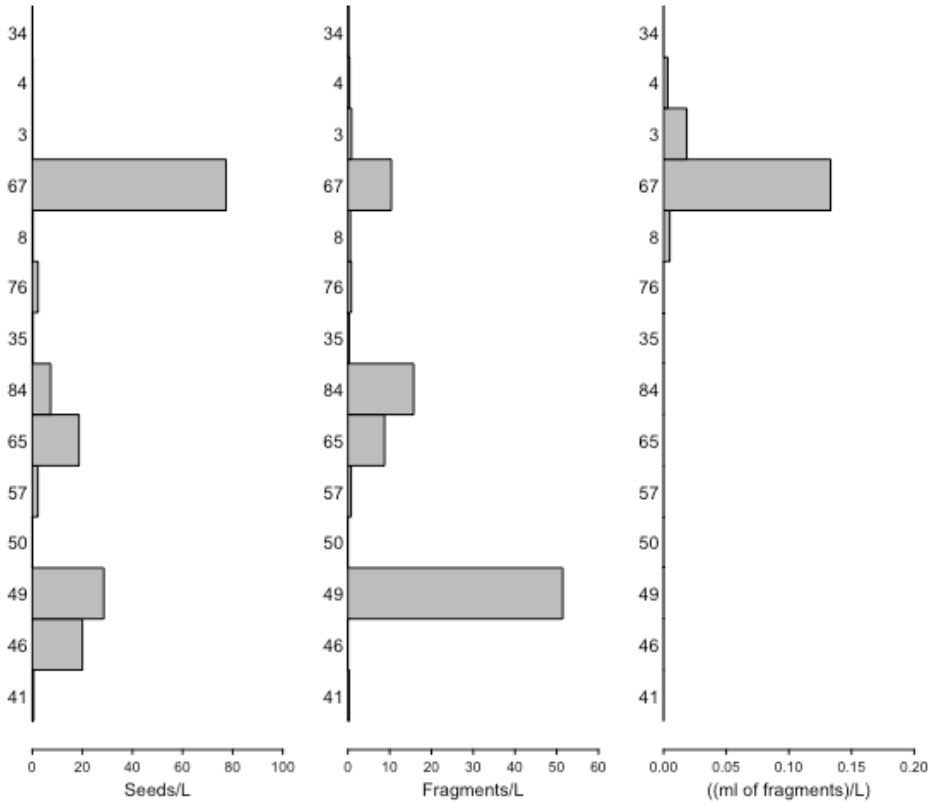


Figure 6.12. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in loci from Area A.

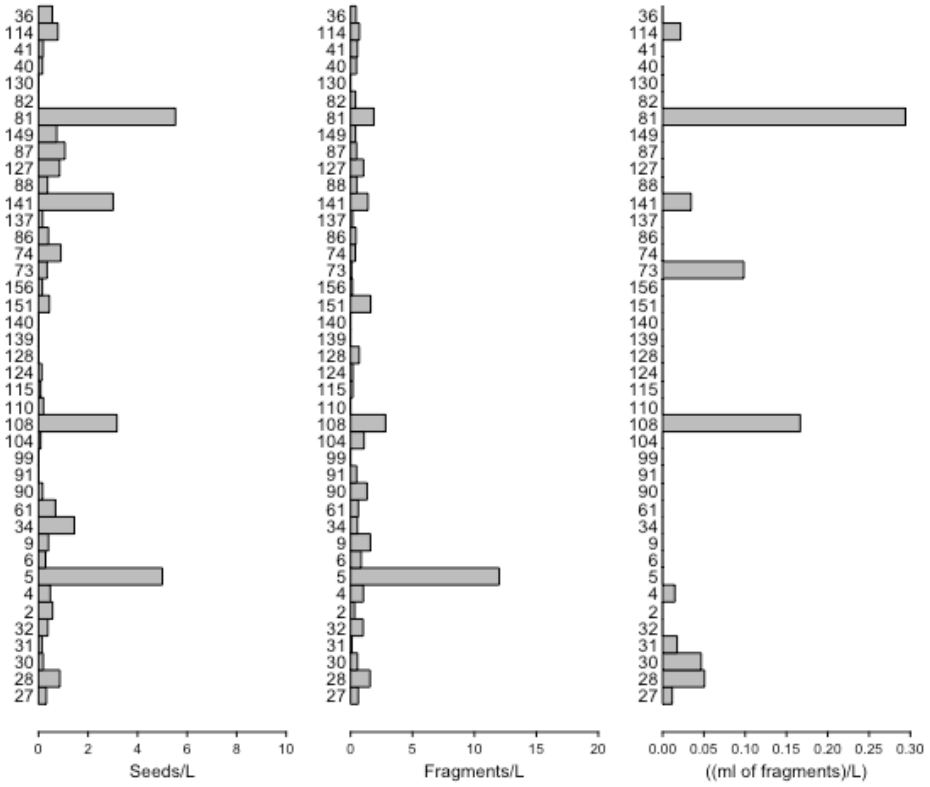


Figure 6.13. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in loci from Area B.

Figure 6.14 and Figure 6.15 combine Figure 6.10–Figure 6.13 to show density by unique locus-square combinations. These figures allow us to pinpoint the highest seed/plant material concentrations within both sites. In Area A (Figure 6.14), the highest density of seeds is in the square/locus combination of AQ36/067 (Hearth; see Table 5.1); this combination also has the highest density of burned mass/tuber-like fragments and a notable concentration of unidentified seed fragments. The highest concentration of fragments is AP36/49 (Dark spot), which also has the second highest seed density. Following these, there are the highest densities in AP36/46 (Dark brown stained area), AP36/65 (Hearth) and AP36/84 (Cut by hearth 67). Highlights from Area B are: a clear demonstration that the highest densities of both seeds and seed fragments are in Square/Locus P3/002 (Dark brown, rich organic sediment). P3/005 (Occupation surface) also has a particularly high density of seed fragments, followed by AW73/81 (Very dark brown deposit/fill), P3/108 (Burnt area), AV74/14 (Loose sandy deposit), AY74/41 (Deposit) and AY74/86 (Mid brown deposit).

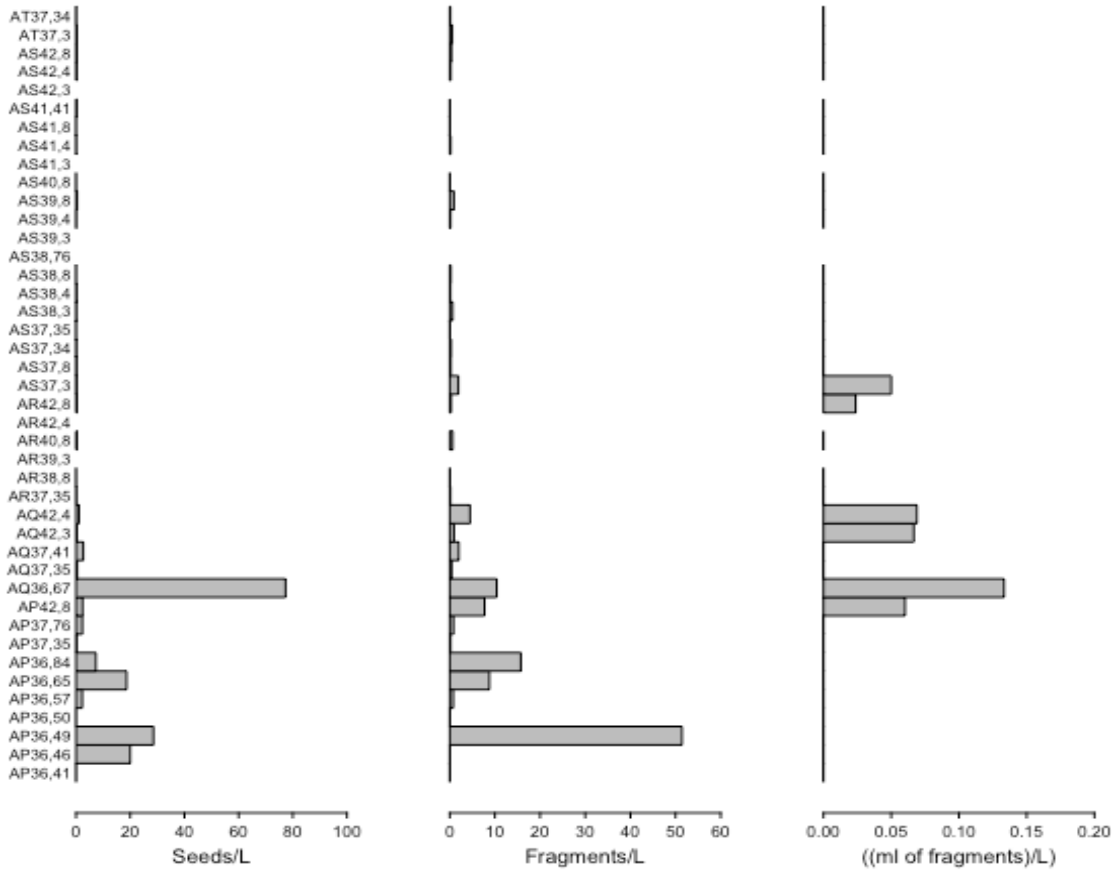


Figure 6.14. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in square/loci combinations from Area A.

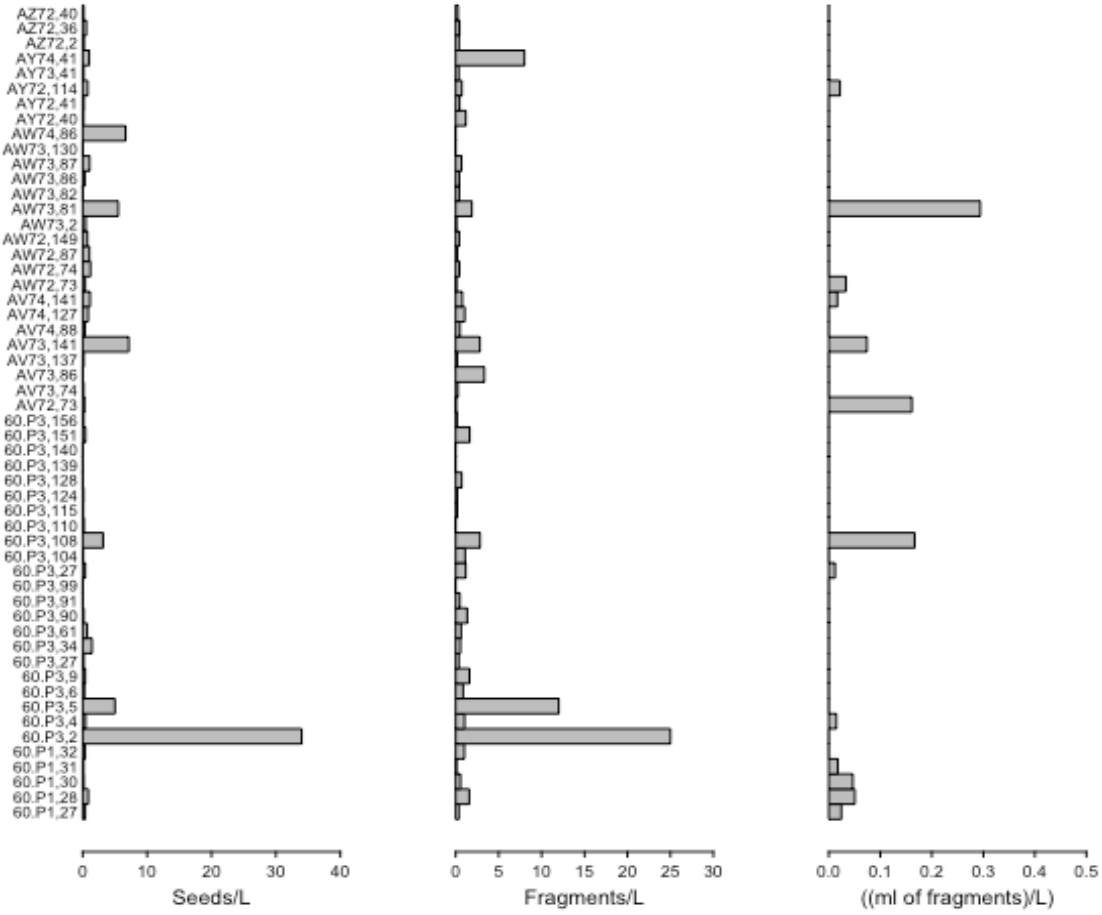


Figure 6.15. Densities of seeds (left), seed fragments (middle) and fragments measured by volume (right) in square/loci combinations from Area B.

Spatial distribution of seed density by area and stratigraphic zone.

Figure 6.16 shows the spatial distribution of the density of seeds for both Area A and Area B. This figure allows us to pinpoint the densest areas over the entire period of occupation at Kharaneh IV. Here in Area A, there is the highest seed densities in the south-western area of the site, specifically square AQ36, followed by AP36. This is similar to the spatial distribution of seed abundance, but the latter did not correct for volume (Figure 6.6). In Area B there is the highest seed density in the southern part of the central site, specifically, squares AW74 and AV73. In contrast to the map for seed abundance with no volume correction (Figure 6.6), squares P1 and P3 did not have an especially high seed density.

Figure 6.17 and Figure 6.18 show the spatial distribution of seed density, divided by stratigraphic zone. In Area A (Figure 6.17), density is relatively similar between

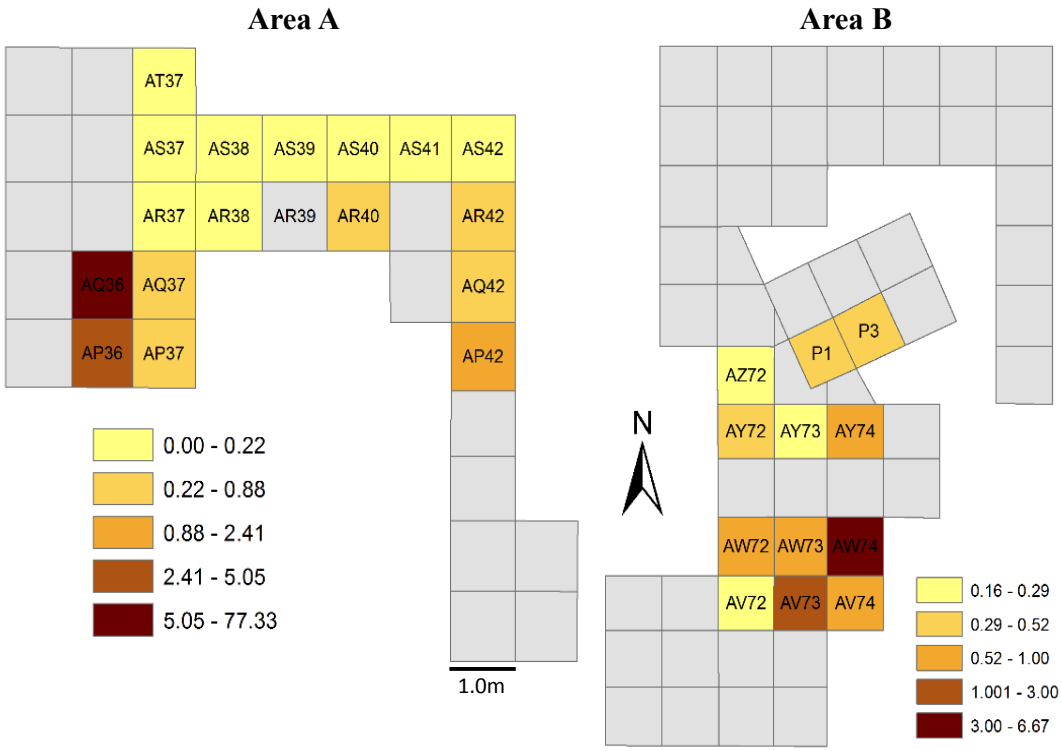


Figure 6.16. Spatial distribution of seed density in Area A and Area B. Note that the colour scales (in seeds/L) differ between the areas.

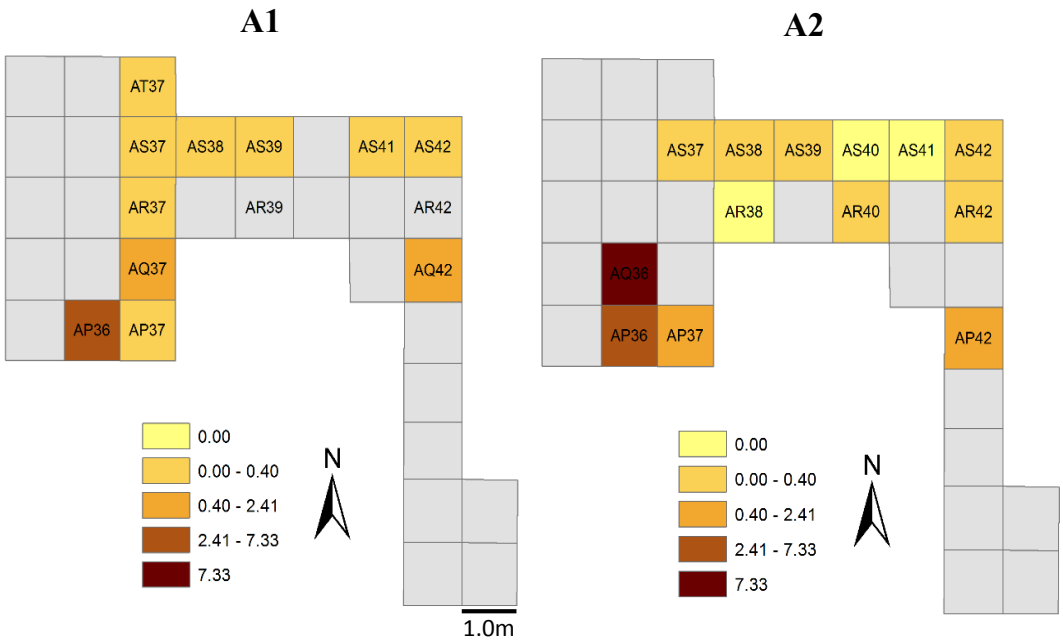


Figure 6.17. Spatial distribution of seed density in stratigraphic zone A1 (left) and A2 (right). Zone A1 is nearest the surface.

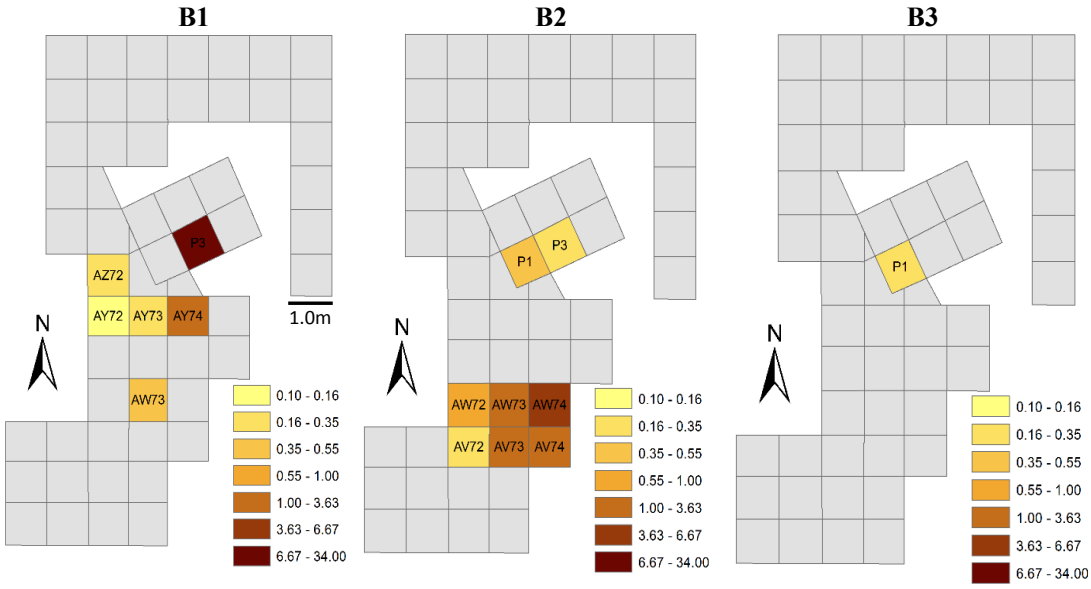


Figure 6.18. Spatial distribution of seed density in stratigraphic zones B1-B3. B3 is the deepest zone and B1 the shallowest.

stratigraphic zones, with the highest density in the southwest. Square AP36 has the highest and second highest density in A1 and A2, respectively. Only square AQ36 has a higher density than AP36 in A2. In Area B's stratigraphic zones (Figure 6.18), density by square is similar, or higher, than in Area A's zones. In B1, P3 in has the highest seed density, followed by AY74. The seed density of P3 in B1 is the highest of any square from within a single stratigraphic zone. In B2, however, P3 is not exceptionally dense, with the highest seed density being found in AW74. Square AW73 was also sampled in both B1 and B2, with a slight increase in density from B1 to B2. P1 was the only square sampled in B3 and it is of intermediate seed density.

Density change between Areas A and B

Figure 6.19 shows the density of seeds per litre by taxon in both Area A (centre) and Area B (left) and then compares the change in density from Area B to Area A (right). This figure allows us to examine the range of taxa present and their abundance, corrected for soil volume throughout the site. Below is a description and contextualization of the evidence in this figure firstly for Area A followed by Area B. Adding to my analysis of the densities of taxa, Table 6.3 depicts the presence and absence of all seed items from both area A and Area B, as well as noting if the taxon is present in both areas.

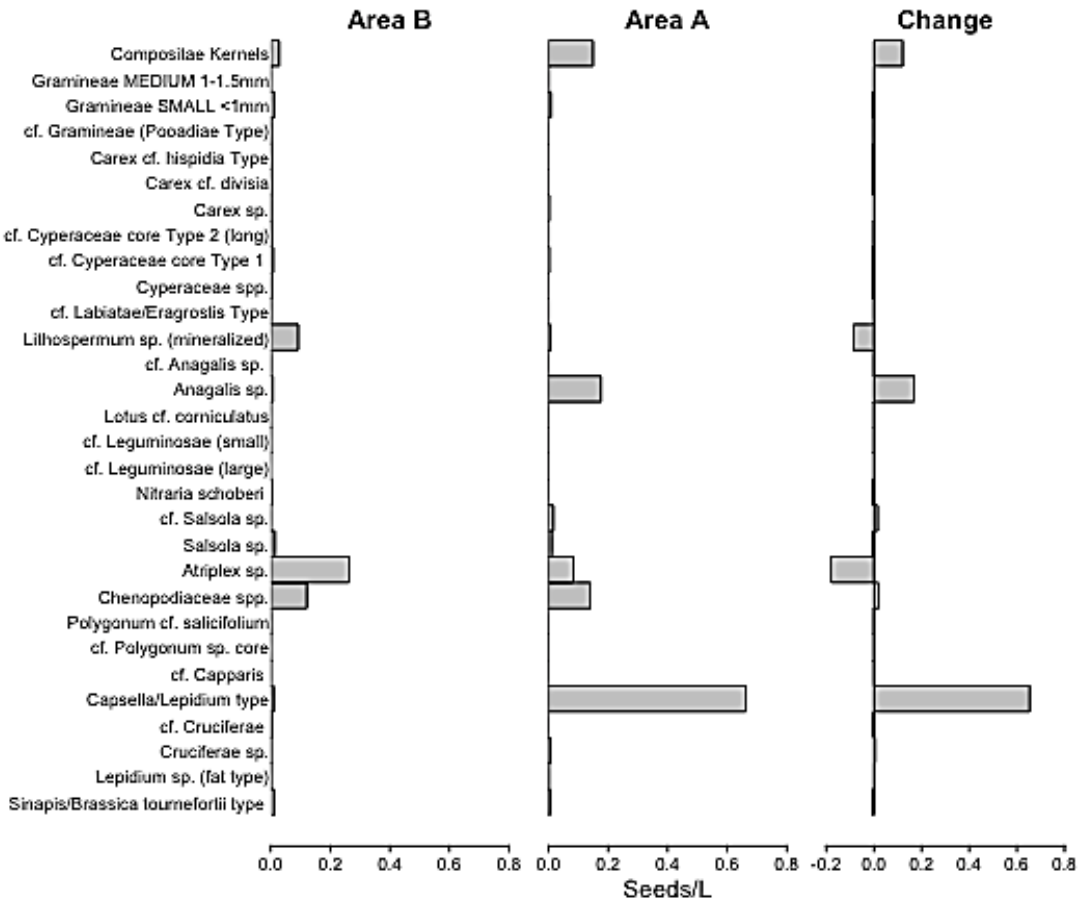


Figure 6.19. Density of seeds (seeds/L) by taxon in Area B and Area A, and the change in density from Area B to Area A.

Area A: In Area A there is a high density of *Capsella/Lepidium* type (Figure 6.19). Most of these seeds originate from square (locus) AQ36 (067), which has been classified as a hearth. Descending in density, *Anagalis* sp. is the next most abundant taxon. This species is clustered primarily in two loci/square locations: AP36 (065), which has been classified by the excavators as a dark stain and the hearth of AQ36 (067). Next, there are the Compositae Kernel type (see: Appendix 3 Seed Catalogue for notes on the identifications), which are present throughout the area, although there is a notable concentration of them in the hearth context of AQ36 (067). Following this, there are Chenopodiaceae spp., which are present across the samples, but have their highest densities in the same hearth context as noted above: AP36 (067). *Atriplex* sp., present across the samples/area, is concentrated in the hearth of AQ36 (067) as well as within AP37 (76), which is the compact floor beside the hearth (067). Next, in declining order, there are lower concentrations *Salsola* sp. (including cf.) again primarily originating from the hearth, AP36 (067). Crucifereae sp.,

Table 6.3. Total abundance by taxon in Areas A and B.

Taxon	Family (FoT)	Plant Part	Area A	Area B	Total
***Sinapis/Brassica tournefortii* type**	Cruciferae	Seed	7	21	**28**
***Sinapis/Brassica tournefortii* type**	Cruciferae	Fragment	6	4	**10**
***Lepidium* sp. (fat type)**	Cruciferae	Seed	3	2	**5**
Cruciferae frag. (large)	Cruciferae	Fragment	7	3	**10**
Cruciferae sp.	Cruciferae	Seed	11	2	**13**
cf. Cruciferae	Cruciferae	Seed	0	4	**4**
***Capsella/Lepidium* type**	Cruciferae	Seed	943	16	**959**
cf. *Capparis*	Capparaceae	Seed	0	1	**1**
cf. *Polygonum* sp. core	Polygonaceae	Core	0	1	**1**
Polygonum* cf. *salicifolium	Polygonaceae	Seed	0	2	**2**
Chenopodiaceae spp.	Chenopodiaceae	Seed	204	202	**406**
Chenopodiaceae	Chenopodiaceae	Fragment	10	0	**10**
***Atriplex* sp.**	Chenopodiaceae	Seed	124	439	**563**
***Salsola* sp.**	Chenopodiaceae	Seed	16	25	**41**
cf. *Salsola* sp.	Chenopodiaceae	Seed	24	1	**25**
Nitraria schoberi	Zygophyllaceae	Seed	0	8	**8**
Nitraria schoberi	Zygophyllaceae	Fragment	10	104	**114**
cf. Leguminosae (large)	Leguminoseae	Seed	1	0	**1**
cf. Leguminosae (small)	Leguminoseae	Seed	0	1	**1**
Lotus* cf. *corniculatus	Leguminosae	Seed	0	1	**1**
***Anagalis* sp.**	Primulaceae	Seed	251	12	**263**
cf. *Anagalis* sp.	Primulaceae	Seed	0	2	**2**
***Lithospermum* sp. (mineralized)**	Boraginaceae	Seed	9	154	**163**
***Lithospermum* sp. Frag**	Boraginaceae	Fragment	3	19	**22**
cf. *Labiatae/Eragrostis* Type	Labiatae/Graminae	Seed	1	2	**3**
Cyperaceae spp.	Cyperaceae	Seed	0	5	**5**
Cyperaceae spp.	Cyperaceae	Fragment	2	2	**4**
cf. Cyperaceae core Type 1	Cyperaceae	Core	4	14	**18**
cf. Cyperaceae core Type 2 (long)	Cyperaceae	Core	1	4	**5**
***Carex* sp.**	Cyperaceae	Seed	4	3	**7**
Carex sp. (mineralized)	Cyperaceae	Fragment	4	0	**4**

Carex* cf. *divisia	Cyperaceae	Seed	0	5	**5**
***Carex* cf. *hispidia* Type**	Cyperaceae	seed	0	5	**5**
cf. Gramineae (Pooadiae Type)	Gramineae	seed	0	3	**3**
Gramineae SMALL <1mm	Gramineae	seed	13	22	**35**
Gramineae SMALL	Gramineae	fragment	3	3	**6**
Gramineae MEDIUM 1-1.5mm	Gramineae	seed	2	1	**3**
Gramineae MEDIUM	Gramineae	fragment	1	8	**9**
Gramineae LARGE >1.5mm	Gramineae	fragment	1	6	**7**
cf. Taeniatherum sp.	Gramineae	fragment	0	1	**1**
***Hordeum* sp.**	Gramineae	fragment	1	12	**13**
Compositae Kernels	Compositae	Kernel	215	48	**263**
Compositae Kernels	Compositae	fragment	80	43	**123**
Small cf. stick fragment	N/A	fragment	0	8	**8**
Folded clump/root knot	N/A	fragment	0	1	**1**
Unidentifiable (indet.) seed	N/A	seed	64	32	**96**
Unidentifiable (indet.) seed fragment	N/A	fragment	347	275	**622**
Unidentifiable (indet.) seed core	N/A	core	23	14	**37**
Small seed core type	N/A	core	9	5	**14**
Unidentifiable (indet.) Non wood frag	N/A	fragment	582	543	**1125**
cf. Fruit flesh	N/A	fragment	3	6	**9**
Reticulate 'Hook' fragments	N/A	fragment	38	3	**41**
Burned masses (small)	N/A	ml	7ml	22ml	**29ml**
Dung like pellet	N/A	pellet	1	2	**3**
Tuber like fragment	N/A	1ml	0	3ml	**3ml**
Tissue with Rugose surface	N/A	fragments	0	3	**3**
Clump of cf. seeds/spores	N/A	fragment	0	1	**1**
fruit/nut shell fragment	N/A	fragment	18	15	**33**
mineralized fruit/nut shell (mineralized)	N/A	fragment	4	1	**5**
vitrified spike/fruit?	N/A	fragment	0	2	**2**

Sinapis/*Brassica tournefortii* type, mineralized *Lithospermum* sp., *Carex* sp. and cf. Cyperaceae core Type 1, are also present throughout Area A but in very low numbers. Though barely visible here due to their low numbers are the grasses. Notably there are a few Small and Medium Gramineae present in AP37 (76), which is the compact floor

locus located beside hearth (067). There are also a few individuals scattered across Area A. Not shown in the figure is the only *Hordeum* sp. fragment from Area A present in the AP36 (067) hearth locus.

Area B: In Area B, *Atriplex* sp. is the most common taxon (Figure 6.19). Notably, the majority of these seeds originate from AV73 (141), which is described as a loose sandy deposit. Descending in density, there are Chenopodiaceae spp., which are present across Area B, but have their highest concentration in AV74 (141), which neighbours the above-mentioned AV73 (141). Following this, there is mineralized *Lithospermum* sp., which are present throughout the area, but are highly concentrated in AW72 (074), which is described as a mid-grey deposit. In the slightly older Area B, there is evidence of the introduction of *Nitraria schoberi*, which are present through the area, but in low numbers (Figure 6.19), and mostly fragmented. The Compositae Kernel type is also present throughout but with its highest concentration in 60.P3 (108) which is described by the excavators as a burnt area. Although present in a few samples, *Sinapis/Brassica tournefortii* type also have their highest concentration in 60.P3 (004). *Capsella/Lepidium* type are present in low numbers (often just a single seed per sample) but in AV73 (141) there are *c*. 5 seeds present. Grasses (Gramineae) are also present across Area B with the highest concentration of Gramineae Small in the popular locus of AV73 (141). Notably, there are also fragments of *Hordeum* sp. in sample 60.P1 (028) described as a deposit. A single and unique (only one found on site) fragment of cf. *Taeniatherum* sp. was found in sample 60.P3 (004), which also contains *c*. 2 Large Gramineae fragments and is described as mid-grey sediment.

Change between B and A: The clearest difference between Area B and Area A is demonstrated in the higher density of *Capsella/Lepidium* type in Area A (Figure 6.19). Area A clearly has higher densities of Compositae Kernels, *Anagalis* sp. and Chenopodiaceae spp.. Compositae Kernel type are present in both Area A and Area B, however the evidence shows comparatively more of these in Area A. In Area B, *Atriplex* sp. are denser than in Area A as well as the mineralized *Lithospermum* sp. Notably rare from Area A (but present in higher abundance in Area B) is *Nitraria schoberi.*

Density change among stratigraphic zones

Figure 6.20 and Figure 6.21 show the density of seeds within the stratigraphic zones, which were assigned to demonstrate diachronic change within Areas A and B and to help reveal a more detailed picture of seed densities over time. Zone B3 represents the deepest stratigraphic zone excavated at Kharaneh IV for which there is samples, and A1 is the uppermost (shallowest) zone, representing the final stages of occupation at Kharaneh IV.

B3 (Figure 6.20**):** Starting at the lowest (oldest) zone, B3, The evidence shows Chenopodiaceae spp. which are the most common taxa followed by Cyperaceae Core Type 1 and *Atriplex* sp. and then *Nitraria schoberi* , *Capsella/Lepidium* type and finally Compositae Kernels.

B2 (Figure 6.20**):** This zone is characterised by the clear dominance of *Atriplex* sp. followed by Chenopodiaceae spp. and the mineralized *Lithospermum* sp. Following this at lower densities there are the Compositae Kernels, *Sinapis/Brassica tournefortii,* Gramineae Small, cf. Cyperaceae Core Type 1, Cyperaceae spp., cf *Labiateae/Eragrostis* Type, *Anagalis* sp., *Nitraria schoberi*, *Salsol*a sp., *Polygonum* cf. *salicifolium*, *Capsella/Lepidium* Type, Cruciferae sp., and *Lepidium* sp. type.

B1 (Figure 6.20**):** This is the most recent (shallowest) collection of samples from Area B. Like B2, they are dominated by *Atriplex* sp., followed by *Lithospermum* sp., Compositae Kernels and Gramineae Small. It is in this zone that there are the most *Carex* spp. (*Carex* cf. *hispidia* type, *Carex* cf. *divisia* type and *Carex* sp.). *Anagalis* sp. and cf. *Anagalis* sp. are also present as well as *Capeslla/Lepidium* type and cf. Crucifereae.

Change between B3 to B2 (Figure 6.20**):** In the deepest (oldest) zone, B3, there are more of the cf. Cyperaceae core Type 1, *Nitraria schoberi*, and *Capsella/Lepidium* type than in Zone B2. In Zone B2 there are more *Atriplex* sp., *Lithospermum* sp., Compositae Kernels, Gramineae Small, *Anagalis* sp., *Salsola* sp. and *Sinapis/Brassica tournefortii* type.

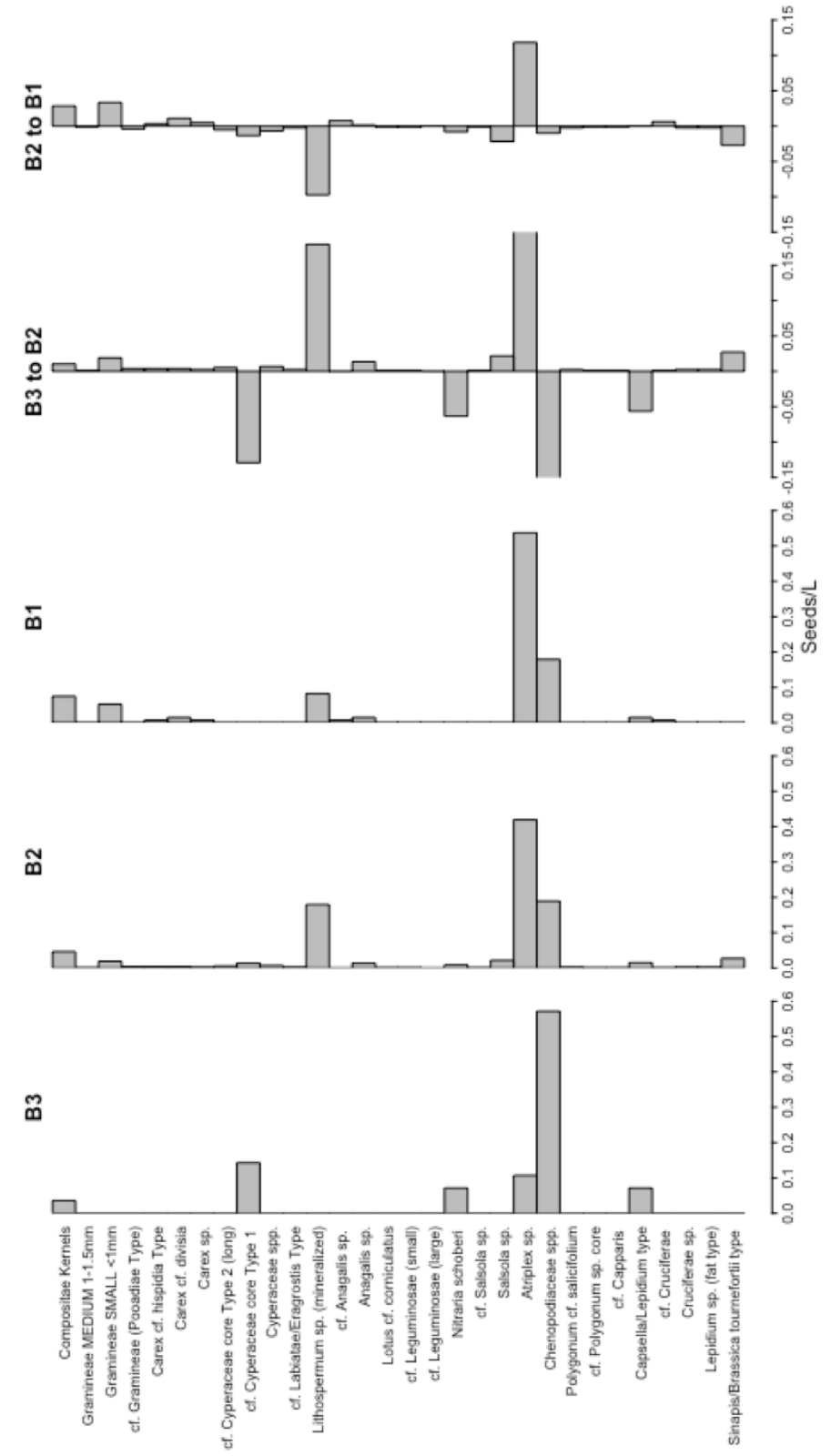


Figure 6.20. Density of seeds by taxon within the Stratigraphic Zones of Area B followed by the change in density between zones.

Change between B2 to B1 (Figure 6.20**):** In B2 there is the highest density of seeds overall and compared to Zone B1 (the final and uppermost zone in Area B) there are more Compositae Kernels, Gramineae Small, *Carex* cf. *hispidia* Type, cf. Cyperaceae core Type 1, *Lithospermum* sp., *Anagalis* sp., *Nitraria schoberi*, *Salsola* sp., *Atriplex* sp., Chenopodiaceae, *Capsella/ Lepidium* type, and *Sinapis/Brassica tournefortii* type. Most importantly, this demonstrates that there is less change than the earlier, deeper zones. In general, changes are greater from B3 to B2 than from B2 to B1.

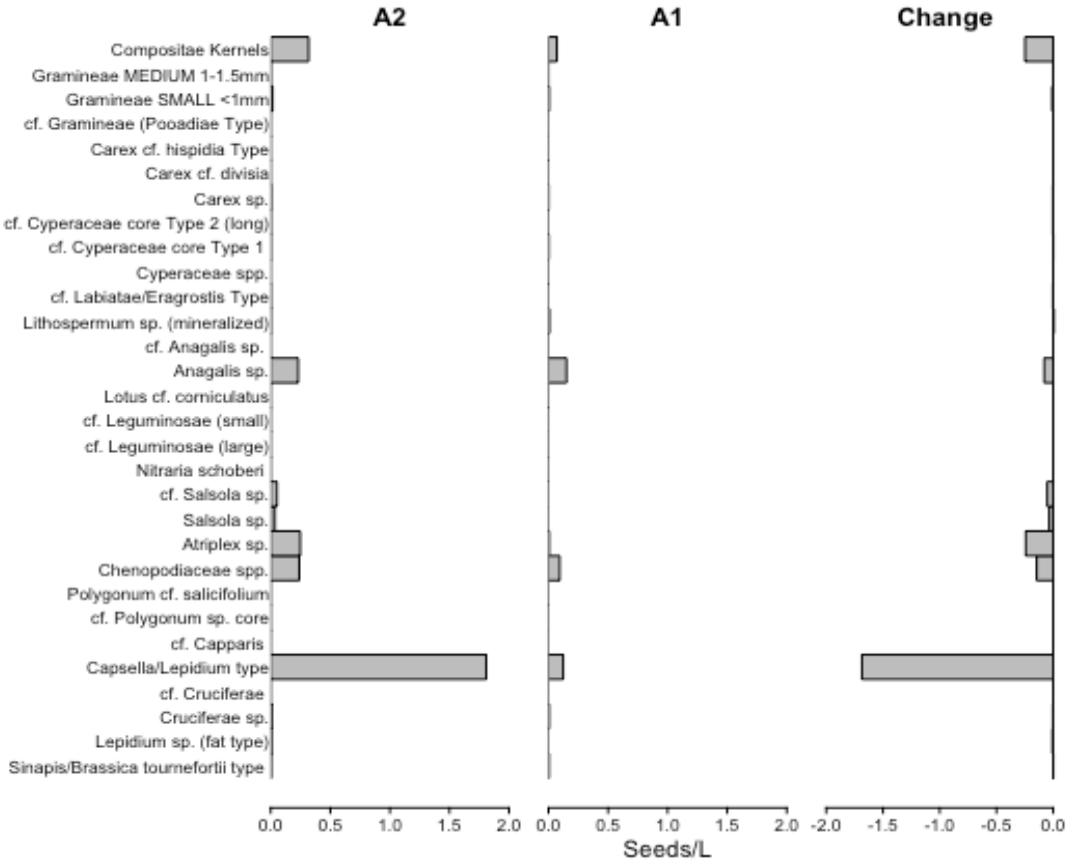


Figure 6.21. Density of seeds by taxon within the Stratigraphic Zones of Area A followed by the change in density between zones.

A1 (Figure 6.21**):** Here the evidence shows somewhat low densities of *Anagalis* sp., *Capsella/Lepidium* type, Chenopodiaceae spp., and Compositae Kernels as well as traces of Gramineae Small, Lithospermum sp., *Atriplex* sp., Crucifereae sp. and *Sinapis/Brassica tournefortii* type.

A2 (Figure 6.21**):** Here there is a high density of *Capesella/Lepidium* Type, followed by Compositae Kernels, *Anagalis* sp., *Atriplex* sp., and Chenopodiaceae spp. Following those, there are smaller densities of *Salsola* sp., Cruciferae sp., *Lepidium* sp. (fat type), and Gramineae small.

Change between A2 to A1 (Figure 6.21**):** Here there is evidence that the older (deeper) A2 has a clear higher density of seeds overall, meaning reductions in density of most taxa from A2 to A1. This is most pronounced in the substantial loss of *Capsella/Lepidium* type, with smaller losses of Compositae Kernel, *Atriplex* sp., Chenopodiacaea, and to a lesser extent, *Anagalis* sp., *Salsola* sp. and cf. *Salsola* sp. and Gramineae Small. This figure demonstrates how the lower densities in A1, relative to the deeper A2 suggest that changes in density are not simply due to more recent deposition in A1.

Relative density

In this section, I present results based on changes in relative density between areas and stratigraphic zones. Relative density was calculated by dividing the density of a taxon by the sum of all taxon densities within an area (or zone). It therefore controls for different amounts of total seeds extracted from each area or zone, and presents changes in the relative abundance (or density), i.e. dominance, of taxa.

Change between A and B: Area A (Figure 6.22**):** As with the above density measures we can clearly see the high relative density of the *Capsella/Lepidium* type. Descending in relative density we still see *Anagalis* sp. and Compositae Kernel type respectively as the next taxa. Following this, there are Chenopodiaceae spp. and *Atriplex* sp. again. Next, there are small concentrations of cf. *Salsola* sp., *Salsola* sp., Gramineae Small (which became more visible in this relative density measure), Crucifereae sp., *Sinapis*/*Brassica tournefortii* type, *Carex* sp. and cf. Cyperaceae Core Type 1. Mineralized *Lithospermum* sp., are also present throughout Area A but in very low numbers.

Area B (Figure 6.22**):** Again, this relative density measure gives us a very similar view as for density, but rarer taxa are more pronounced. *Atriplex* sp. is the most common taxon. Descending in relative density, there are Chenopodiaceae spp.,

followed by mineralized *Lithospermum* sp, and the introduction of *Nitraria schoberi*. The Compositae Kernel type is also present throughout. Although present in a low numbers there are *Sinapis/Brassica tournefortii* type, *Capsella/Lepidium* type and grasses (Gramineae), including a seed of *Hordeum* sp.

Change between B and A (Figure 6.22**):** This figure highlights the change in relative density between Area B and A. Most notably, there are more *Capsella/Lepidium* type and *Anagalis* sp. in Area A than in Area B. Also, in Area A there are relatively more Compositae Kernels, *Salsola* sp. and Crucifereae sp. Alternatively, in Area B there are relatively more *Atriplex* sp., *Lithospermum* sp., and Chenopodiaceae spp. Also in Area B there are relatively more *Sinapis/Brassica tournefortii* type and Gramineae Small as well as the unique presence of complete *Nitraria schoberi* seeds.

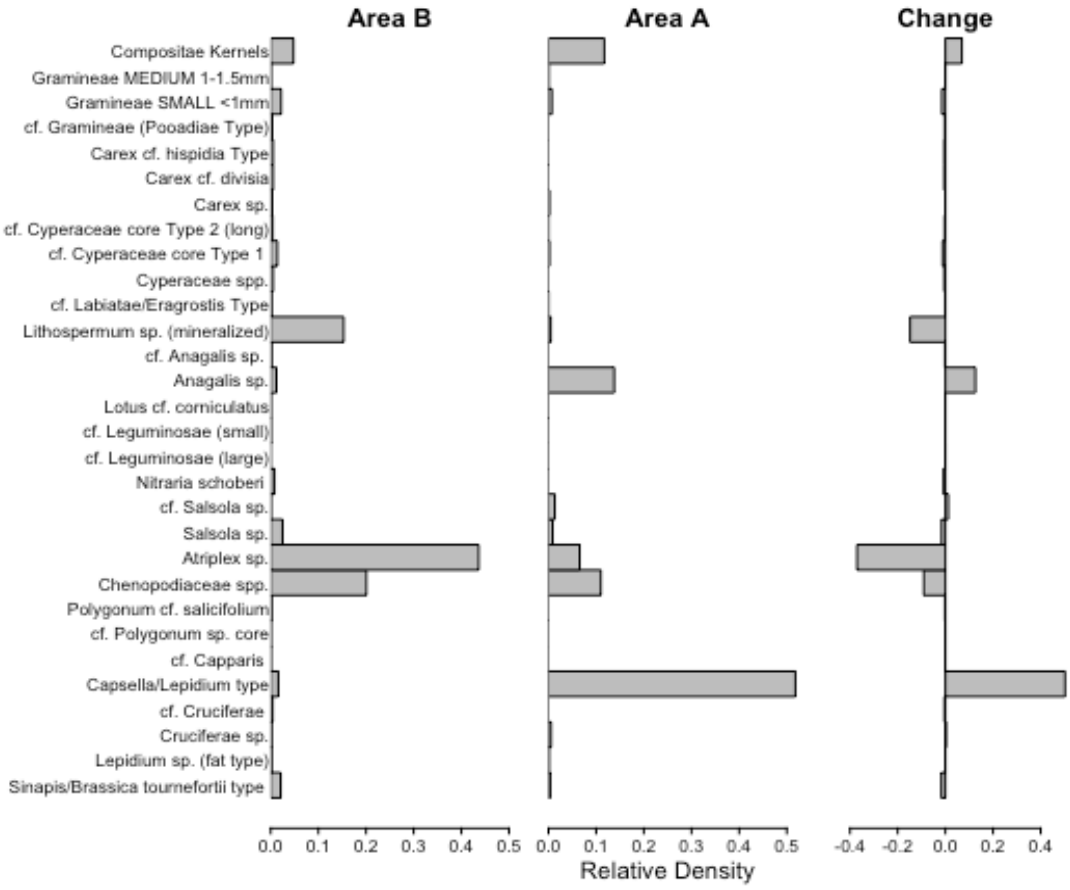


Figure 6.22. Relative density of seeds by taxon in Area B and Area A, and the change in relative density from Area B to Area A.

Change among stratigraphic zones: Figure 6.23 and Figure 6.24 show the relative density of seeds in Areas B and A, respectively, diachronically divided by stratigraphic zone with B3 the deepest stratigraphic zone and A1 representing the final stages of occupation at Kharaneh IV.

B3 (Figure 6.23**):** Starting at the lowest (oldest) zone, B3, again there is a very similar result to the density measures (Figure X.25), but with low density taxa more pronounced. As with the density measures, Chenopodiaceae spp. are the most common taxa followed by Cyperaceae Core Type 1, *Atriplex* sp., *Nitraria schoberi*, *Capsella/Lepidium* type and finally Compositae Kernels.

B2 (Figure 6.23**):** This zone has the highest diversity of species and is characterized by a clear dominance of *Atriplex* sp. followed by Chenopodiaceae spp. and the mineralized *Lithospermum* sp. Following this at lower relative densities there are the Compositae Kernels, *Sinapis/Brassica tournefortii,* Gramineae Small, cf. Cyperaceae Core Type 1, Cyperaceae spp., cf *Labiateae/Eragrostis* Type, *Anagalis* sp., *Nitraria schoberi*, *Salsol*a sp., *Polygonum* cf. *salicifolium*, *Capsella/Lepidium* Type, Cruciferae sp., and *Lepidium* sp. type.

B1 (Figure 6.23**):** This is the most recent (highest) collection of samples from Area B and is dominated again by *Atriplex* sp., followed by *Lithospermum* sp., Compositae Kernels and Gramineae Small. It is in this zone that there is the most *Carex* spp. (*Carex* cf. *hispidia* type, *Carex* cf. *divisia* type and *Carex* sp.). Here *Anagalis* sp. and cf. *Anagalis* sp. are also present, as well as *Capeslla/Lepidium* type and cf. Crucifereae.

Change from B3 to B2 (Figure 6.23**):** Most notable here is the difference/flip between the density and the relative density analysis in Chenopodiaceae spp. Here there is a higher relative density of Chenopodiaceae spp. in B3. The following have similar results as for the density plots with more of the cf. Cyperaceae core Type 1, *Nitraria schoberi*, and *Capsella/Lepidium* type than in Zone B2. In Zone B2 we also have relatively more *Atriplex* sp., *Lithospermum* sp., Compositae Kernels, Gramineae Small, *Anagalis* sp., *Salsola* sp. and *Sinapis/Brassica tournefortii* type.

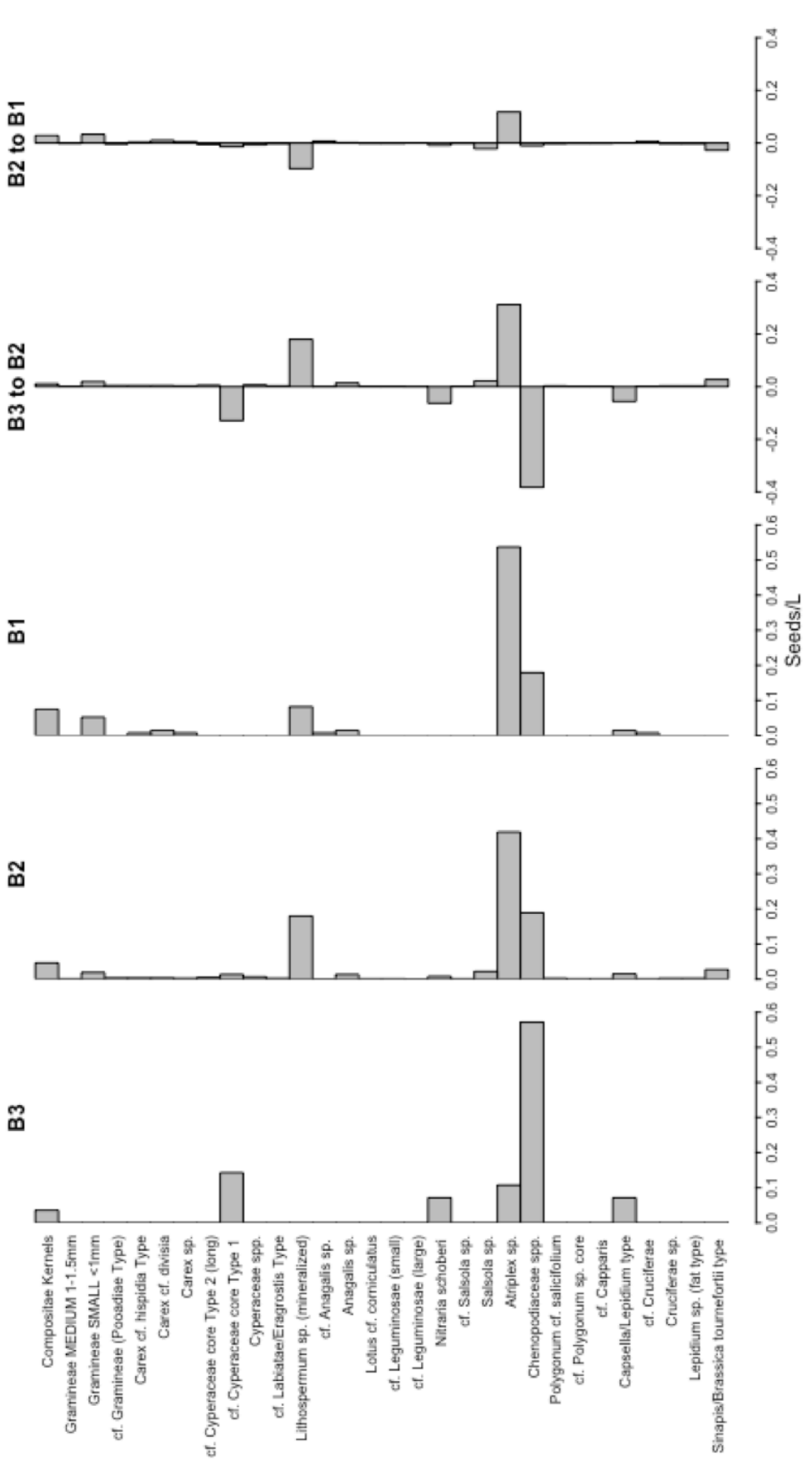


Figure 6.23. Relative density of seeds within Stratigraphic Zones of Area B and the change in relative density between zones

Change from B2 to B1 (Figure 6.23**):** Here we also have a flip in the results between the density and relative density analysis for *Atriplex* sp., which has a higher relative density in B1 as opposed to B2 in the density measure. Similar to the density measures, there is the highest density of seeds overall in B2 and compared to B1 (the final and uppermost zone in Area B) there are more Compositae Kernels, Gramineae Small, *Carex* cf. *hispidia* Type, cf. Cyperaceae core Type 1, *Lithospermum* sp., *Anagalis* sp., *Nitraria schoberi*, *Salsola* sp., *Atriplex* sp., Chenopodiaceae, *Capsella/ Lepidium* type, and *Sinapis/Brassica tournefortii* type. Most importantly, this demonstrates that by the B1 zone there is less change than the earlier, deeper zones.

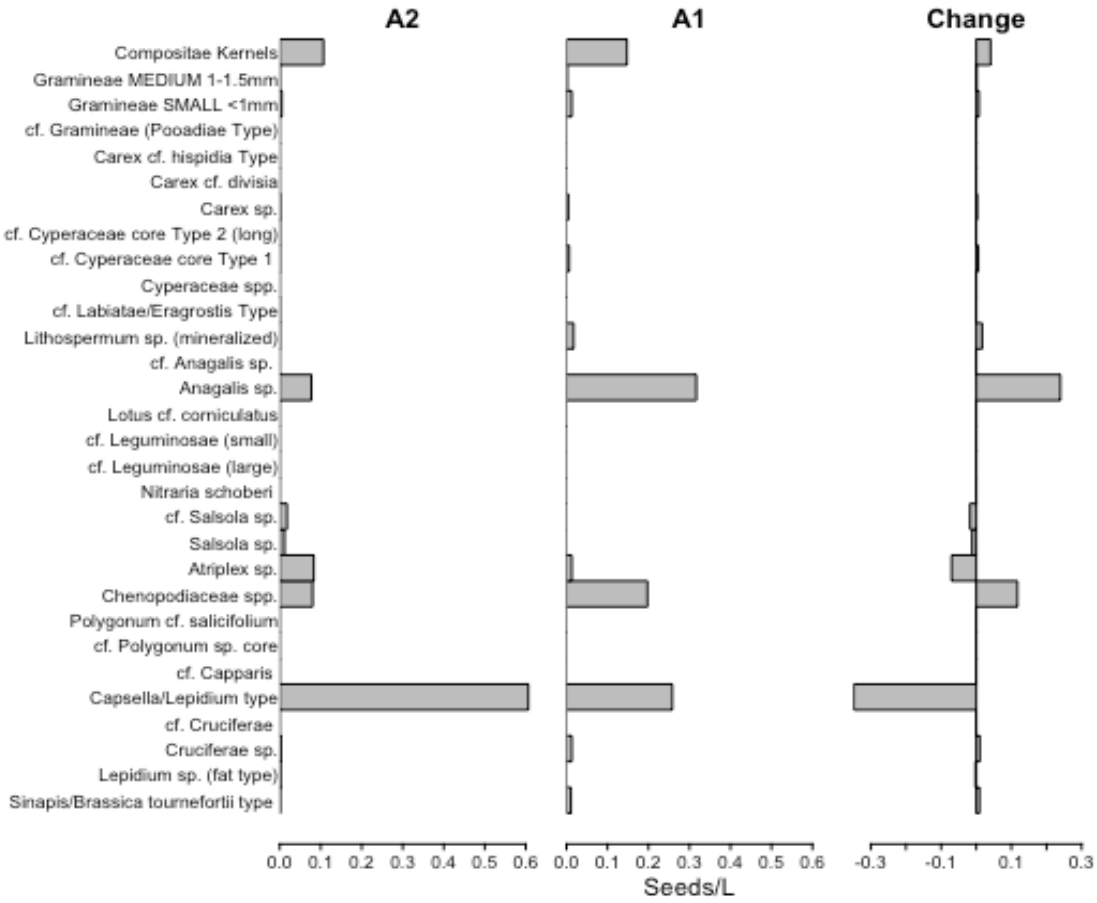


Figure 6.24. Relative density of seeds by taxon within stratigraphic Zones of Area A and the change in relative density from A2 to A1.

A2 (Figure 6.24**):** Here there is very little difference between density and relative density measures, with the exception of *Capesella/Lepidium* type. The density and relative density of *Capesella/Lepidium* type is clearly dominant. We still have

Compositae Kernels, *Anagalis* sp., *Atriplex* sp., and Chenopodiaceae spp. present. Following those, there are lower densities of *Salsola* sp., Cruciferae sp., *Lepidium* sp. (fat type), and Gramineae small.

A1 (Figure 6.24**):** Unlike the density measures presented above, in A1 there are comparatively high relative densities of *Anagalis* sp., *Capsella/Lepidium* type, Chenopodiaceae spp., and Compositae Kernels, highlighting the usefulness of this analysis in accounting for total density of material when dealing with very small total numbers of seeds. In addition, the traces of Gramineae small, *Lithospermum* sp., *Atriplex* sp., Crucifereae sp. and *Sinapis/Brassica tournefortii* type have become more evident when considering relative density.

Change from A2 to A1 (Figure 6.24**):** As with density, the major change in relative density is a reduction in the dominance of *Capsella/Lepidium* type from A2 to the more recent A1. Additionally, while density declined in all taxa, the relative density of Compositae Kernals, *Anagalis* sp., and Chenopodiaceae spp. decreased in A2.

6.8. Diversity and rarefaction

In this section, I switch focus from the abundance and density of seeds and individual taxa to a focus on diversity, or taxonomic richness, i.e. the number of taxa and/or types recovered from each area and stratigraphic zone. I consider the number of seed taxa per 100 litres of soil (Taxa Density). 100L, rather than 1L was used simply to make expressing units on plots more convenient. I also carry out rarefaction analysis to account for differences in the amount of archaeobotanical material (specifically number of seeds) obtained from different areas/zones, which can confound comparisons of number of taxa and taxa density.

Figure 6.25 and Figure 6.26 show diversity by area and stratigraphic zone. Figure 6.25 shows the number of seed taxa, uncorrected for the volume of soil extracted, while Figure 6.26 corrects for the volume of soil, presenting taxa density (number of taxa per litre of soil). Area B has more diversity, with over 30 different taxa compared to 20 in Area A. This pattern was driven by the high number of seed taxa found in B2. Diversity, uncorrected for soil volume, was very low in B3, the deepest zone, while Area A showed far less change though in A1, the uppermost zone, there are slightly

fewer taxa. Correcting for the amount of soil in each area/zone (Figure 6.26) showed that Area B was still more diverse. However, in the stratigraphic zone analysis, B3 was the most diverse, given the amount of soil while B2 was actually less diverse. Correcting for soil volume also showed that A1 has the lowest diversity, per 100 litres of soil.

Rarefaction

Rarefaction is a way to account for different sample sizes (number of seeds) in diversity comparisons. It corrects not just for the different number of seeds extracted from different areas, but also how diversity accumulates with increasing sample size. In particular, diversity tends to increase quickly, which can make the diversity of small samples appear inflated (see Methodology in Chapter 6).

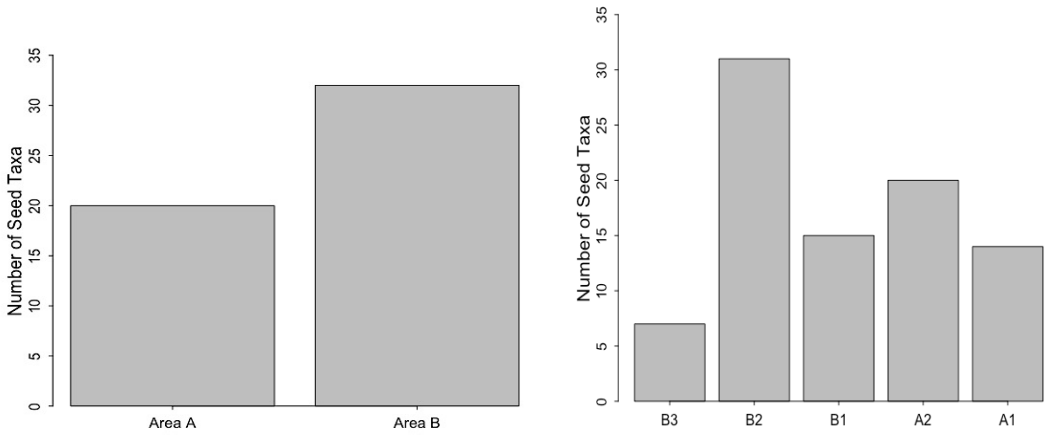


Figure 6.25. Number of seed taxa (diversity) by area and stratigraphic zone. Zone B3 is the deepest (oldest) and A1 is the uppermost (youngest).

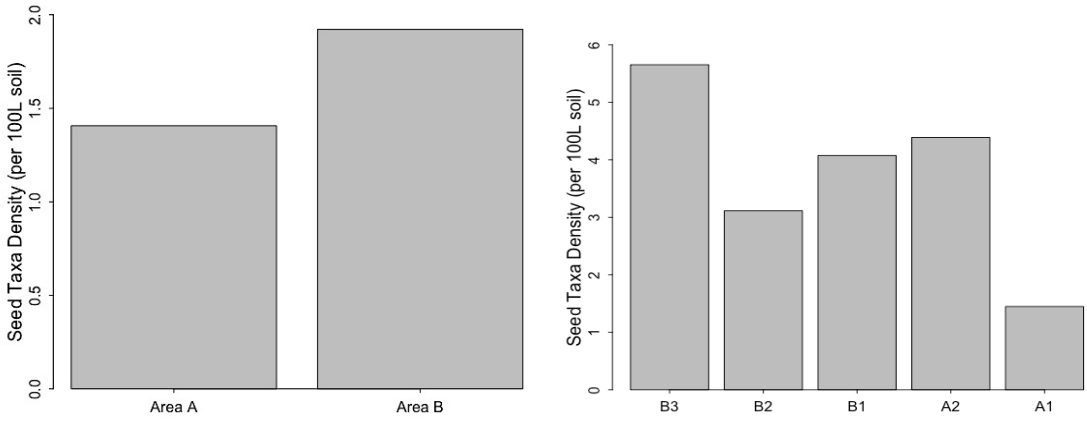


Figure 6.26. Seed taxa density (the number of seed taxa per 100 litres of soil), a measure of diversity, by area and stratigraphic zone. Zone B3 is the deepest (oldest) and A1 is the uppermost (youngest). Taxa density is expressed as per 100L of soil rather than per litre simply for convenient formatting of units.

Figure 6.27 shows the rarefaction analysis comparing the taxa richness (number of seed taxa) to sample size for Areas A and B. For Area A, taxa richness plateaus at around 20, suggesting that regardless of whether or not we could add more samples, we have reached a plateau in the total taxa richness we might expect to find. In contrast, Area B continues to climb, above 30 without plateauing. This suggests that further sampling from this area would likely increase the diversity of taxa found in Area B. These plots also confirm that higher diversity of Area B compared to Area A.

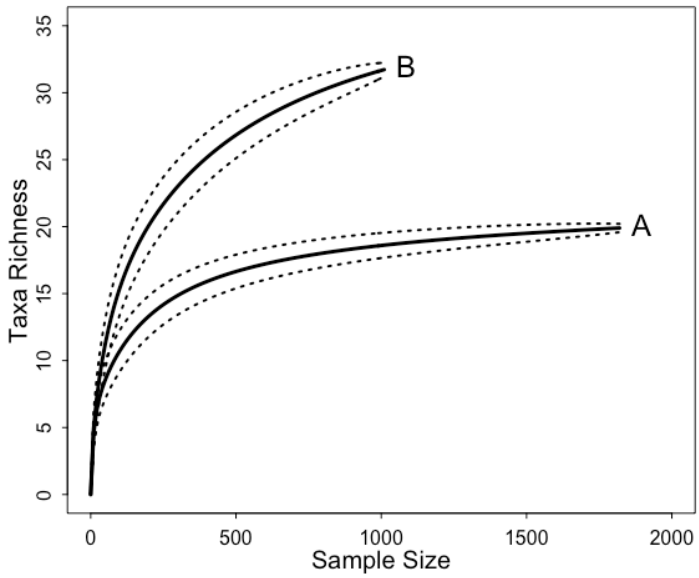


Figure 6.27. Rarefaction analysis with standard errors (dashed lines) comparing the taxa richness to sample size for Area A and Area B.

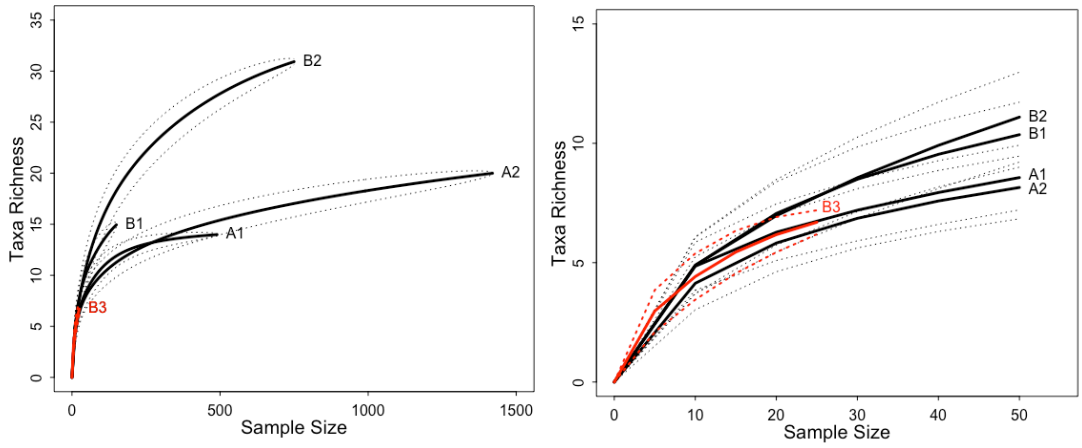


Figure 6.28. Rarefaction curves, with standard errors (dashed lines) comparing the taxa richness of each Stratigraphic zone. The left panel shows the entire range of sample sizes for each zone and the right sample sizes from 0 to 50, to highlight patterns at small sample sizes. Zone B3 is shown in red simply to make it visible given high overlap with other curves.

Figure 6.28 shows rarefaction curves by stratigraphic zone for the entire range of sample sizes extracted for each zone (left panel), and for sample sizes 1 to 50 (right panel, to better display patterns with small samples). The figure shows that B2 is by far the most diverse zone, in contrast to the taxa density results (Figure 6.27). A1 appears to have the lowest diversity, though there is overlap of standard errors with A2. However, the A1 curves appears to have flattened out, suggesting that even if more seeds were recovered, diversity is unlikely to increase. Although there is likely undiscovered seed diversity in zones B3, B2, B1 and A2, it is clear that B1 and B2 are more diverse than A1 and A2. In contrast, the right panel of Figure 6.28 suggests that B3 may be less diverse than the other B zones, more closely matching the diversity of Zone A. However, the small sample size from B3 means that any conclusions must be made carefully regarding the diversity of this zone, as there are undoubtedly many undiscovered taxa.

6.9. Correspondence analysis (CA)

Table 6.4 shows taxa names and their corresponding codes used for the correspondence analysis (CA). Table 6.5 and Table 6.6 show the identification Codes (ID) used in the CA to represent samples in Area A and Area B respectively.

Table 6.4. Taxa and associated codes used in correspondence analysis (CA).

Taxon	CA Code
Sinapis/Brassica tournefortii type	SinBr
Lepidium sp. (fat type)	Lepi
Capsella/Lepidium type	CapLp
Cruciferae sp.	Cru
cf. *Capparis*	cfCap
Polygonum cf. *salicifolium*	PlcfSal
Chenopodiaceae spp.	ChenS
Atriplex sp.	Atx
Salsola sp.	Sal
Nitraria schoberi	Nit
cf. Leguminosae (large)	cfLegL
cf. Leguminosae (small)	cfLegS
Lotus cf. *corniculatus*	Lot
Anagalis sp.	Ana
Lithospermum sp. (mineralized)	Lith
cf. *Labiatae/Eragrostis* Type	cfLabE
Cyperaceae sp.	Cyp
cf. Cyperaceae core Type 1	cfCyp1
cf. Cyperaceae core Type 2 (long)	cfCyp2
Carex sp. (mineralized)	CarM
Carex cf. *divisia*	CarcfD
Carex cf. *hispidia* Type	CarcfH
cf. Gramineae (Pooideae?/Setaria? Type)	cfGpoo
cf. *Taeniatherum sp.*	cfTae
Hordeum spp.	HordF
Gramineae LARGE	GrLF
Gramineae MEDIUM	GrM
Gramineae SMALL	GrS
cf. Compositae Kernel	ComK

Table 6.5. Area A identification codes (ID) and descriptions for correspondence analysis (CA).

ID	Square	Locus	Description	Stratigraphic Rank
1001	AP36	041	Compact sediment	A1
1002	AP36	046	Dark brown stained area	A1
1003	AP36	049	Dark Spot	A1
1004	AP36	050	Dark Spot	A1
1005	AP36	057	Deposit	A1
1006	AP36	065	Hearth	A1
1007	AP36	084	Compact sediment,cut by hearth 67	A2
1008	AP37	035	Sediment beside hearth	A1
1009	AP37	076	Compact Floor, beside hearth (067)	A2
1010	AP42	008	Compact light brown sediment	A2
1011	AQ36	067	Hearth	A2
1012	AQ37	035	Sediment beside hearth	A1
1013	AQ37	041	Compact sediment	A1
1014	AQ42	003	Occupation Surface	A1

1015	AQ42	004	Occupation Surface	A1
1016	AR37	035	Sediment beside hearth	A1
1017	AR38	008	Compact light brown sediment	A2
1018	AR39	003	Occupation Surface	A1
1019	AR40	008	Compact light brown sediment	A2
1020	AR42	004	Occupation Surface	A1
1021	AR42	008	Occupation Surface	A2
1022	AS37	003	Occupation Surface	A1
1023	AS37	008	Compact light brown sediment	A2
1024	AS37	034	Hearth	A1
1025	AS37	035	Sediment beside hearth	A1
1026	AS38	003	Occupation Surface	A1
1027	AS38	004	Occupation Surface	A1
1028	AS38	008	Occupation Surface	A2
1029	AS38	076	Compact Floor, beside hearth (067)	A2
1030	AS39	003	Occupation Surface	A1
1031	AS39	004	Occupation Surface	A1
1032	AS39	008	Occupation Surface	A2
1033	AS40	008	Occupation Surface	A2
1034	AS41	003	Occupation Surface	A1
1035	AS41	004	Occupation Surface	A1
1036	AS41	008	Compact light brown sediment	A2
1037	AS41	041	Compact sediment	A1
1038	AS42	003	Occupation Surface	A1
1039	AS42	004	Occupation Surface	A1
1040	AS42	008	Occupation Surface	A2
1041	AT37	003	Occupation Surface	A1
1042	AT37	034	Hearth	A1

Table 6.6. Area B identification codes (ID) and descriptions for correspondence analysis (CA).

ID	Square	Locus	Description	Stratigraphic Rank
2001	60.P1	027	Deposit	B2
2002	60.P1	028	Deposit	B2
2003	60.P1	030	Alternating occupation surfaces and refuse. Miden?	B3
2004	60.P1	031	Deposit	B3
2005	60.P1	032	Alternating occupation surfaces and refuse. Miden?	B3
2006	60.P3	002	Dark-brown rich organic sediment	B1
2007	60.P3	004	Occupation Surface/mid grey sediment	B2
2008	60.P3	005	Occupation surface	B2
2009	60.P3	006	Deposit	B2
2010	60.P3	009	Deposit	B2
2011	60.P3	027	Deposit	B2
2012	60.P3	034	Deposit	NA

2013	60.P3	061	Deposit	B2
2014	60.P3	090	Light grey silty clay deposit	B2
2015	60.P3	091	Mid brown silty clay deposit	B2
2016	60.P3	099	Whiteish sediment	B2
2017	60.P3	027	Mid brown Sediment/Deposit	B2
2018	60.P3	104	Dark brown deposit	NA
2019	60.P3	108	Burnt area	B2
2020	60.P3	110	Light grey deposit	B2
2021	60.P3	115	Light brown bone concentration	B2
2022	60.P3	124	Occupation surface/ compact with white clay	B2
2023	60.P3	128	Loose bone layer in orange clay	B2
2024	60.P3	139	Ashy charcoal and bone concentration	B2
2025	60.P3	140	Bone layer "big"	B2
2026	60.P3	151	Grey loose ashy deposit	B2
2027	60.P3	156	Sterile clay	B2
2028	AV72	073	Light grey silt deposit	B2
2029	AV73	074	Mid grey deposit	B2
2030	AV73	086	Mid brown deposit	B2
2031	AV73	137	Dark deposit	NA
2032	AV73	141	Loose sandy silt deposit	B2
2033	AV74	088	Bone layer	NA
2034	AV74	127	Soft loose bone layer	NA
2035	AV74	141	Soose sandy silt deposit	B2
2036	AW72	073	Light grey silt deposti	B2
2037	AW72	074	Mid grey deposit	B2
2038	AW72	087	Compact deposit with burnth lithics	B2
2039	AW72	149	Loose sandy deposit	B2
2040	AW73	002	Floor/ Dark brown rich organic sediment	B1
2041	AW73	081	Very dark brown deposit/fill	B2
2042	AW73	082	Very dark brown to black hearth fill	NA
2043	AW73	086	Mid brown deposit	B2
2044	AW73	087	Compact deposit with burnt lithics	NA
2045	AW73	130	Loose brown deposit beneath lithics scatter (95)	NA
2046	AW74	086	Mid brown deposit	B2
2047	AY72	040	Occupation Surface	B1
2048	AY72	041	Deposit	B1
2049	AY72	114	Dark deposit	NA
2050	AY73	041	Deposit	B1
2051	AY74	041	Deposit	B1
2052	AZ72	002	Dark brown rich organic sediment	B1
2053	AZ72	036	Deposit	B1
2054	AZ72	040	Deposit	B1

CA results for all samples and seeds

Figure 6.29 shows the results of a CA that included all samples and seed abundances (fragments were excluded). Dimension one accounts for 21.1% of the variation in seed abundance and composition of samples and dimension two accounts for 17.1%,

giving a total of 28.2% explained. Thus, the overall differentiation of samples based on seed abundances is relatively weak. The plot does show the differentiation of samples into those containing *Lithospermum sp.* (Lith in plot) and those without. Samples with *Lithospermum sp.,* which were all in Area B, are the main source of differentiation between the two areas. The *Lithospermum sp.* found were all mineralized, rather than carbonized. The high abundance of *Lithospermum sp.* in some samples dominates the correspondence analysis and potentially obscures more archaeobotanically meaningful relationships. Therefore, I repeated the Correspondence analysis excluding *Lithospermum* sp. below.

Figure 6.30 shows the results of CA on all samples, excluding *Lithospermum sp.* Excluding *Lithospermum sp.* allows for a clearer depiction of relationships among taxa and samples. Dimension 1 explains 22% of the variation and Dimension 2 only 13.8%, for a total of 25.8%, suggesting that only a quarter of the variation in composition among samples is explained by these two dimension, i.e. the differentiation is rather weak. There is a weak cluster of similar samples from Area A with negative values on Dimension 1. These samples are characterized by *Anagalis* sp. (Ana), cf. *Salsola* sp. (cfSal), *Capsella/Lepidium* type (CapLP), and cf. Compositae Kernels (comK). A less distinct cluster of primarily (but not completely) Area B samples has high values along Dimension 2 and contain cf. *Capparis* (cfCap),

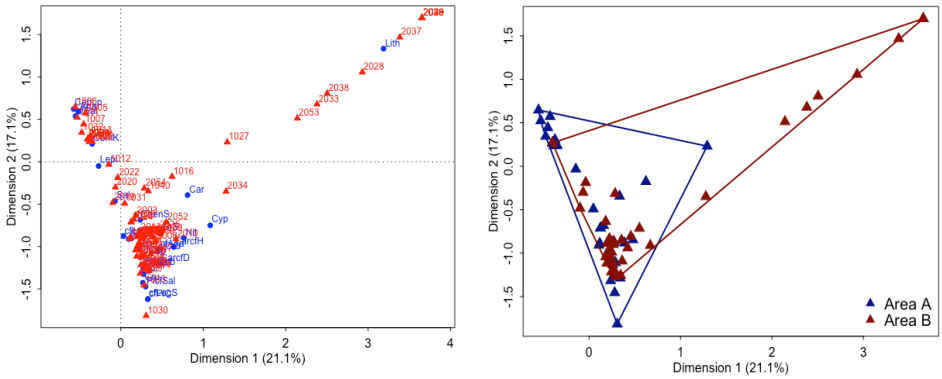


Figure 6.29. Correspondence analysis on seed abundance across all samples from both Areas A and B. Sample numbers with 1000s are Area A, 2000s are Area B. Taxa codes are given in Table 6.4 and sample code IDs are given in Table 6.5 for Area A and Table 6.6 for Area B. The right panel delineates samples from Area A and B using minimum convex polygons.

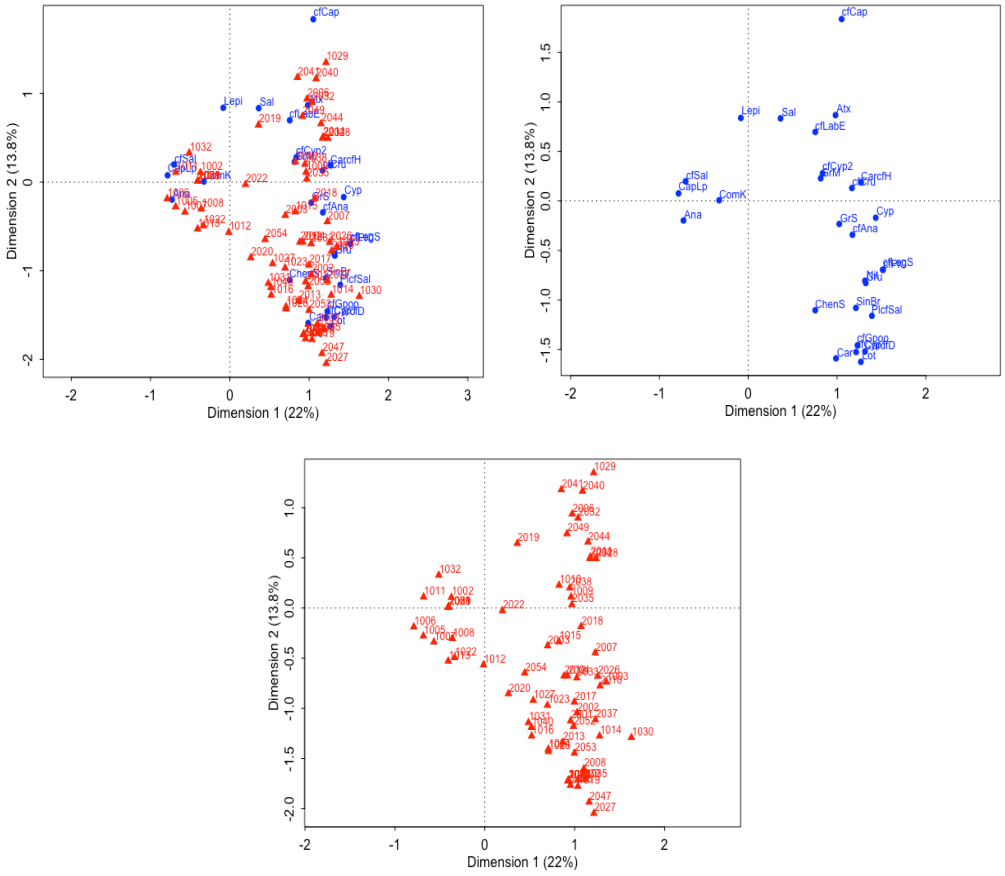


Figure 6.30. Correspondence analysis on all samples, excluding *Lithospermum sp.* The top left shows samples (red) and taxa (blue) overlaid. The top right shows only taxa and the bottom only samples for clarity. Sample and taxa codes are found in Table 6.4 and sample IDs are given in Table 6.5 for Area A and Table 6.6 for Area B. Samples from Area A begin with 1 and samples from Area B begin with 2.

Atriplex sp. (Atx), cf. *Labiatae/Eragrostis* Type (cfLabE) and *Salsola* sp. (Sal). Figure 6.30 also shows that there may be some slight arching in the correspondence analysis, which could arise from samples at the end of the arch having few species in common, or non-linearity in similarity among samples (Quinn and Keough 2000). However, if present, this effect is slight and unlikely to confound interpretation of the general patterns.

Figure 6.31 shows the differentiation between samples in Area A and B from correspondence analysis excluding *Lithospermum* sp. Here, I have used minimum convex polygons to delineate the space occupied by Area A (blue) and Area B (red) samples. There is very little differentiation with substantial overlap between the two

areas. This demonstrates that there are not strong, consistent differences in the composition of samples from Area A versus those in Area B. Noting the clump samples from Area A on the left, which is already mentioned above.

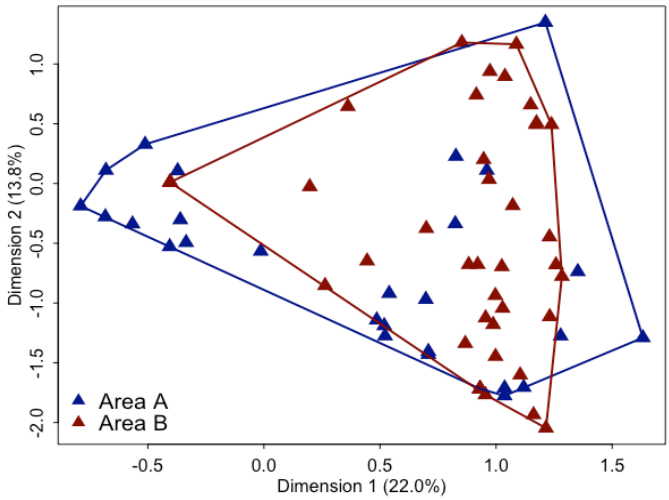


Figure 6.31. Correspondence analysis of Area A and Area B samples excluding *Lithospermum sp.* using minimum convex polygons to delineate the space occupied by Area A (blue) and Area B (red) samples.

Figure 6.32 shows the distribution of samples in CA space by stratigraphic zone, using minimum convex polygons to delineate the space occupied by each stratigraphic zone's samples. The evidence shows a clear pattern of nestedness here, where B2, B1 and A2 are all quite similar but B3 and A1 (the extreme stratigraphic layers with B3 lowest and A1 uppermost) are subsets of what is found in the middle-stratigraphic layers. None of the samples in these zones have the high frequency of *Atriplex* sp. (Atx), *Salsola* sp. (Sal), cf. *Capparis* (cfCap), and cf. *Labiatae/Eragrostris* Type (cfLabE) that is present in some samples in zones B2, B1, and A2.

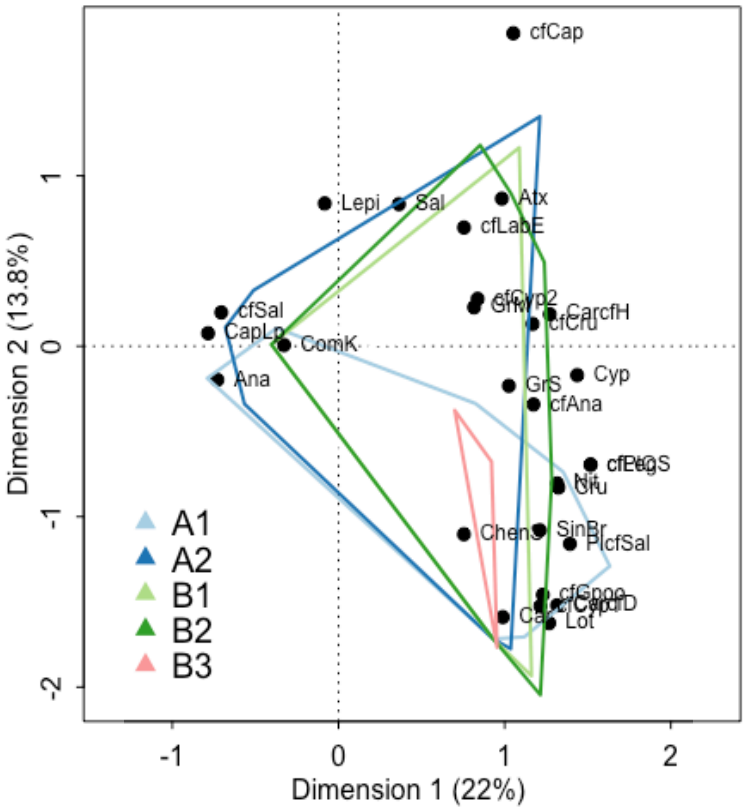


Figure 6.32. . Correspondence analysis showing the distribution of samples and their stratigraphic zone with taxa codes superimposed. Taxa codes are given in Table 6.4.

Figure 6.33 shows all samples with families superimposed for both Areas A and B. This CA explained more variation than the previous one (62.4% for the first two axes compared to 28.2%). The majority of the samples are clustered together, with the exception of those with Boriganaceae (*Lithospermum* sp.), which sit as outliers, as, was found with the previous CA.

Figure 6.34 shows all samples with families superimposed for both A and B with the outlier (Boriganaceae) removed. Here we still see a clustering of the majority of the samples, however, we can now detect wider separation along Dimension 1, which explains 41.1% of the variation. Notably, a series of samples from Area A are distinct as having relatively high amounts of Primulaceae, while others from both Areas A and B have high levels of Compositae and Cruciferae, with the latter over represented especially in several samples from Area A.

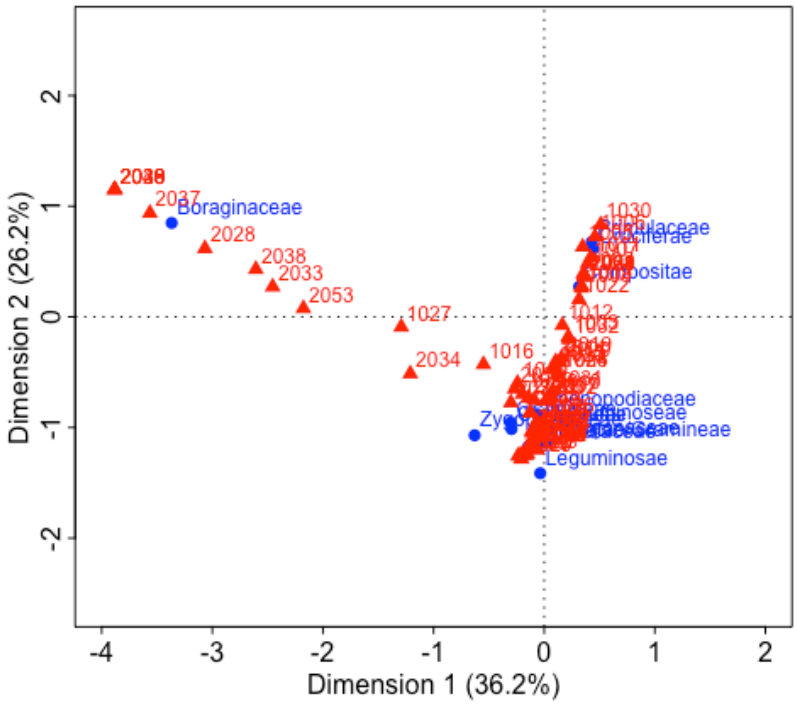


Figure 6.33. Correspondence analysis of all samples (red triangles) from Area A and Area B using Family (blue circles) as the lowest unifying classification. Samples beginning with 1 are from Area A and 2 are from Area B.

Correspondence analysis at Family level

The above correspondence analysis includes seeds identified to different taxonomic levels, which could confound the results. Thus, I repeated the CA at the family level, which was the lowest taxonomic level to which all seeds could be assigned consistently.

Figure 6.35 and Figure 6.36 show the overlap between areas and stratigraphic zones at the family level. There is a greater distinction between Area A and B samples than in the previous CA, driven primarily by the Area A samples with especially high Cruciferae and especially Primulaceae. Unlike the taxonomically unstandardized CA, samples from A1 were not clearly nested within those of other stratigraphic zones, but instead showed more intrazone variability, again primarily due to those samples with relatively high amounts of Primulaceae and, to a lesser extent, Cruciferae.

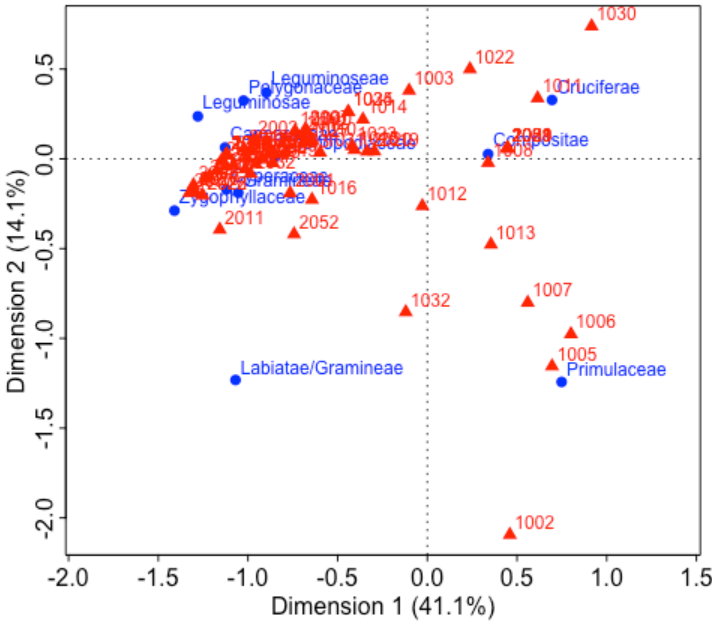


Figure 6.34. Correspondence analysis of all samples from Area A and Area B using Family as the lowest unifying classification and excluding the outlier (Boraginaceae). Sample codes are given in Table 6.5 and Table 6.6. Samples from Area A begin with 1 and samples from Area B begin with 2.

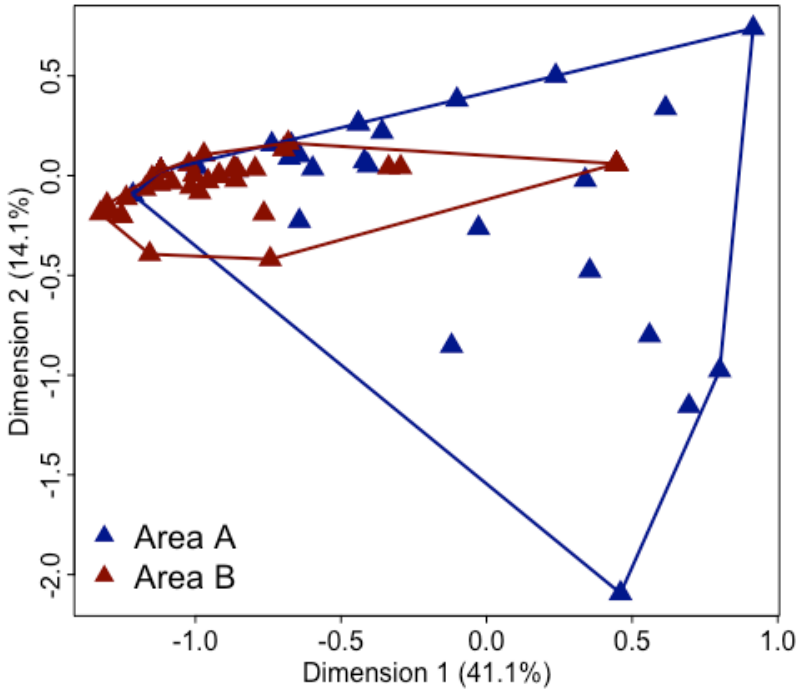


Figure 6.35. Correspondence analysis at the Family level excluding Boraginaceae. Minimum convext polygons delineate the space occupied by Area A (blue) and Area B (red) samples.

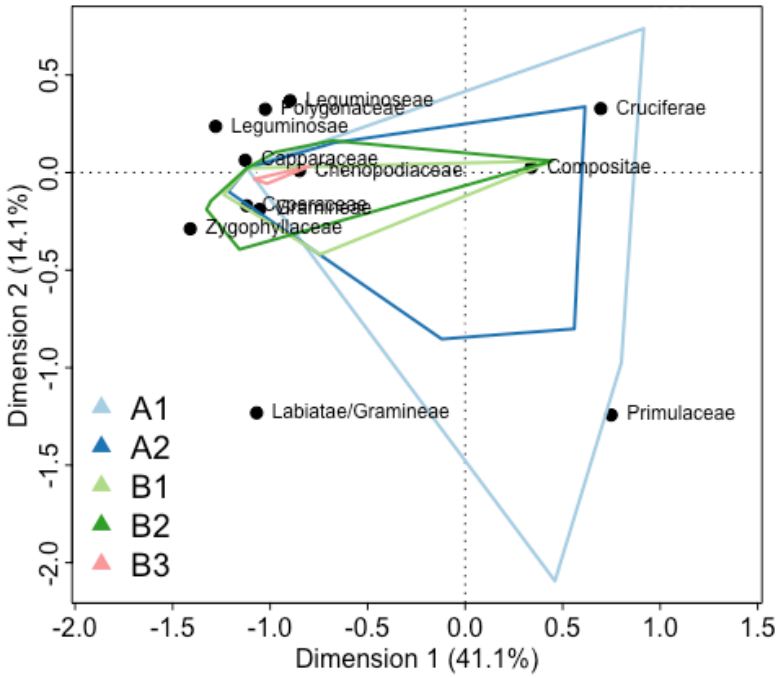


Figure 6.36. Correspondence analysis at the Family level, excluding Boraginaceae, showing the distribution of samples and their stratigraphic zone (minimum convex polygons) with Families superimposed.

6.10. Habitat preference (wet-dry) and ecological generalisations

Table 6.7 lists the identified taxa at Kharaneh IV along with a generalised ecology/habitat description for each taxon (see Appendix 3: Seed Catalogue). Taxa were classified as either having a preference for dry or wet habitats. Generalists were classified as 'varied'.

Table 6.7. List of identified taxa and a generalised description and classification of their habitat extracted from the Seed Catalogue (Appendix 3). For further information and details on each taxon see the Seed Catalogue.

Taxon	CA Code	Family	Generalised Ecology/Habitat Description	Classification
Sinapis/Brassica tournefortii type	SinBr	Cruciferae	Waste Places, wind blown, sandy arid, or semi-arid environments	DRY
Lepidium sp. (fat type)	Lepi	Cruciferae	Wide ranging: Deserts and wet places, saline, waste places	VARIED
Capsella/Lepidium type	CapLp	Cruciferae	Cultivated land, waste places	VARIED
Cruciferae sp.	Cru	Cruciferae	Majority of species occupy arid habitats with minimal annual rainfal.	VARIED
cf. Cruciferae	cfCru	Cruciferae	Majority of species occupy arid habitats with minimal annual rainfal.	DRY
cf. *Capparis*	cfCap	Capperaceae	Arid, disturbed land, rock outrops	DRY

Polygonum cf. *salicifolium*	PlcfSal	Polygonaceae	Wet places, marshy lowlands, Swamps near sea level	WET
Chenopodiaceae spp.	ChenS	Chenopodiacaea	Dry temperate and warm temperate areas, tolerate salty soils, grow in dry steppes or semideserts.	DRY
Atriplex sp.	Atx	Chenopodiacaea	Deserts and wadi beds	DRY
Salsola sp.	Sal	Chenopodiacaea	Deserts, Dry, Saline	DRY
Nitraria schoberi	Nit	Zygophyllaceae	Sandy, Dry, Salty	DRY
cf. Leguminosae (large)	cfLegL	Leguminoseae	Worldwide distribution (except Antarctica and high Artic), shrubs predominantly outside tropics.	VARIED
cf. Leguminosae (small)	cfLegS	Leguminoseae	Worldwide distribution (except Antarctica and high Artic), shrubs predominantly outside tropics.	VARIED
Lotus cf. *corniculatus*	Lot	Leguminoseae	Humid, damp heavy soil	WET
Anagalis sp.	Ana	Primulaceae	Marshy, cultivated land river banks clay soil rocky slopes	VARIED
Lithospermum sp. (mineralized)	Lith	Boraginaceae	Limestone slopes, field margins,rocky, steppe	VARIED
cf. *Labiatae/Eragrostis* Type	cfLabE	Labiatae/Gramineae	Steppe/dry/ cultivated/disturbed	DRY
Cyperaceae sp.	Cyp	Cyperaceae	Associated with wetlands or poor soils	WET
cf. Cyperaceae core Type 1	cfCyp1	Cyperaceae	Associated with wetlands or poor soils	WET
cf. Cyperaceae core Type 2 (long)	cfCyp2	Cyperaceae	Associated with wetlands or poor soils	WET
Carex sp. (mineralized)	CarM	Cyperaceae	Wet places, Marshes, ditches by streams, saltmarshes	WET
Carex cf. *divisia*	CarcfD	Cyperaceae	Wet places, Marshes, ditches by streams, saltmarshes	WET
Carex cf. *hispidia* Type	CarcfH	Cyperaceae	Wet places, Marshes, ditches by streams, saltmarshes	WET
cf. Gramineae (Pooideae?/Setaria? Type)	cfGpoo	Gramineae	Cool weather/ disturbed grounds	VARIED
cf. *Taeniatherum sp.*	cfTae	Gramineae	Dry, steppe grassy, slopes, stony hillsides, scrub, sandy plains	DRY
Hordeum spp.	HordF	Gramineae	Steppe river banks lake margins fields roadsides	VARIED
Gramineae LARGE	GrLF	Gramineae	Worldwide distribution (except Antarctica)	VARIED
Gramineae MEDIUM	GrM	Gramineae	Worldwide distribution (except Antarctica)	VARIED
Gramineae SMALL	GrS	Gramineae	Worldwide distribution (except Antarctica)	VARIED
cf. Compositae Kernel	ComK	Compositae	Worldwide distribution except Antarctica and extreme Arctic.	VARIED

Ecological generalisations between Areas A and B

Figure 6.37 shows changes in seed density (number of seeds per litre) and taxa density (number of taxa per litre of soil) between Areas A and B for taxa with different habitat

preferences. The density of seeds from taxa that prefer wet or dry habitats both declined from Area B to Area A, with an increase in generalist (varied) taxa. A X^2 (chi-squared) test indicates that these differences in the proportion of seeds in each category are significant among areas (X^2=761.4, df=2, P<<0.0001). The density of varied habitat seeds is high in area A. Also of interest, in Area B, dry seeds/L is higher than in A, and that there are more wet seeds in Area B than in Area A.

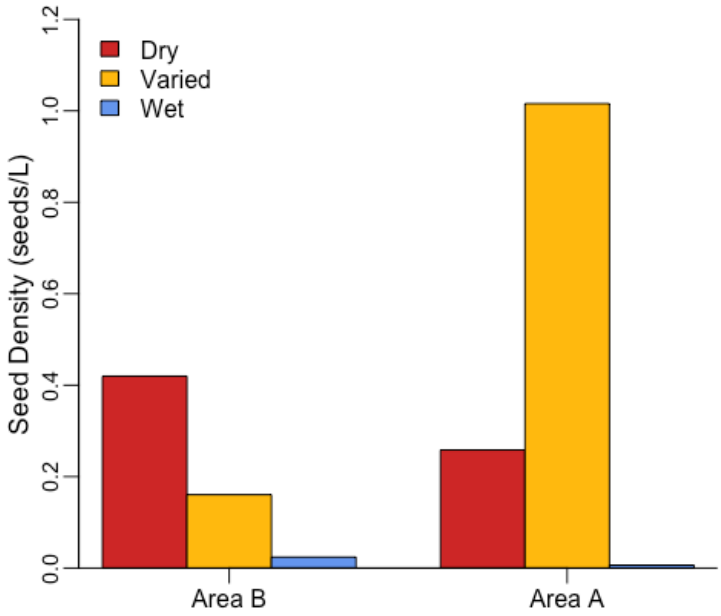


Figure 6.37. Density of seeds (/L) of taxa that prefer wet, dry or varied (generalists) habitats in Areas A and B. Habitat generalisations are given in Table 6.7.

Figure 6.38 show changes in taxa density (number of taxa per litre of soil) between Areas A and B. Area B contains more wet taxa than dry, while Area A, which includes the latest stages of occupation experiences a drop in wet habitat specialists, relative to dry-preferring species. However, a X^2 test suggests these changes are not significant (X^2=1.025, df=2, P=0.60), though the low number of taxa means that the reliability of the X^2 tests is questionable (Quinn and Keough 2000).

Ecological generalisations by stratigraphic zone.

Figure 6.39 shows seed density of taxa with different habitat preferences across stratigraphic zones. There are several general trends. Density of seeds from 'dry' taxa are lowest in B3 and A1, the most extreme zones (B3: lowest, A1: uppermost). The density of seeds from taxa that prefer wet habitats tends to decline as stratigraphy

becomes shallower, with the lowest density of 'wet' seeds in A1. A X^2 tests confirms that the relative proportions of seeds from taxa with different habitat preferences differs across zones (X^2=713.0, df=8, P<<0.0001).

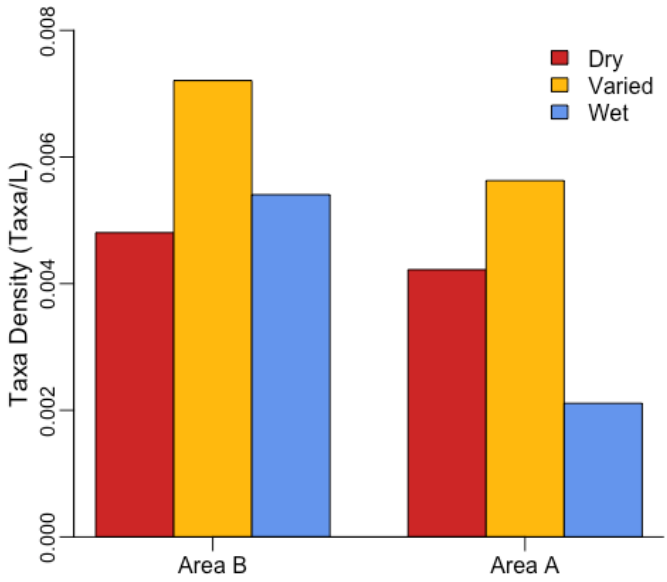


Figure 6.38. Density of taxa (number of taxa/L), a measure of diversity, that prefer wet, dry or varied (generalists) habitats in Areas A and B. Habitat generalisations are given in Table 6.7.

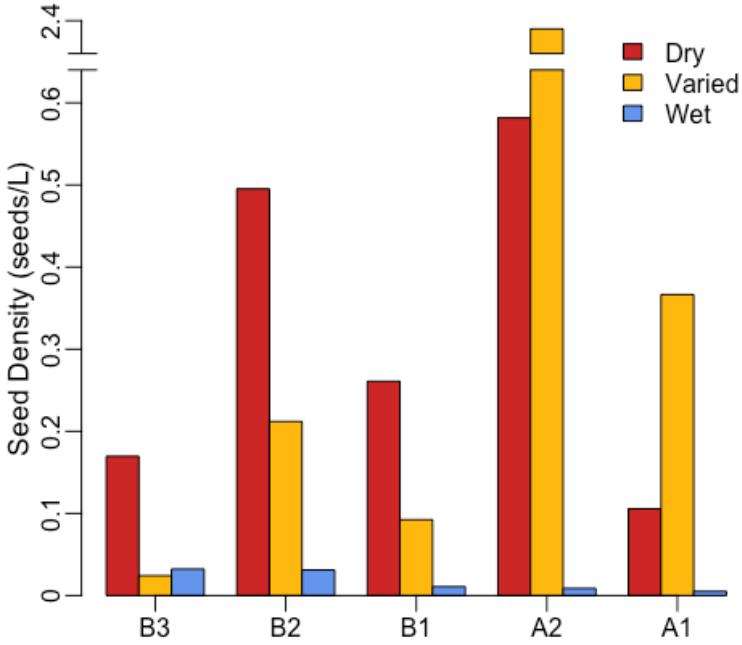


Figure 6.39. Density of seeds (/L) of taxa that prefer wet, dry or varied (generalists) habitats by stratigraphic zone. Zone B3 is the deepest (oldest) and Zone A1 is uppermost (youngest). Habitat generalisations are given in Table 6.7.

Figure 6.40 shows the taxa density (number of taxa per litre of soil) of taxa with different habitat preferences across stratigraphic zones. Diversity of wet taxa both tend to decline from deeper to shallower stratigraphic zones, with the biggest drop occurring from A2 to A1. There is also low diversity of dry and varied taxa in A1, though these diversities are more variable across zones. There is an exceptionally high diversity of dry-preferring taxa in B3, though given the small sample sizes from these areas; this should be interpreted cautiously. As with the comparison among zones, the X^2 test was not significant (X^2=4.54, df=8, P=0.80), but the small number of counts in each category mean that this test is not necessarily reliable (Quinn and Keough 2000).

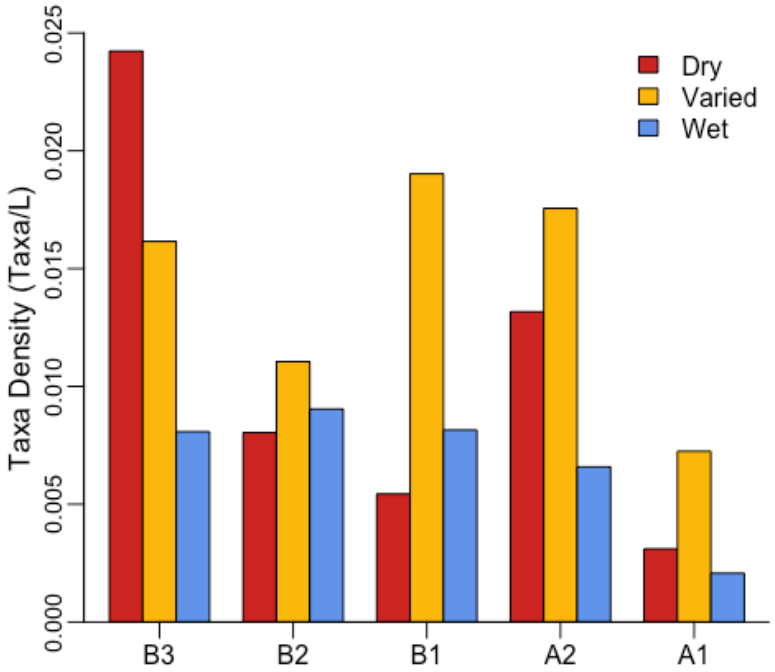


Figure 6.40. Density of taxa (number of taxa/L), a measure of diversity, that prefer wet, dry or varied (generalists) habitats by stratigraphic zone. Zone B3 is the deepest (oldest) and Zone A1 is uppermost (youngest). Habitat generalisations are given in Table 6.7.

Chapter 7. Taphonomic Considerations for Kharaneh IV and the Epipalaeolithic in the Southern Levant

7.1. General taphonomic considerations

Before discussing the archaeobotanical results, here I review the taphonomic conditions that have, in many ways, contributed to the archaeobotanical information available from Kharaneh IV and all other archaeological sites where archaeobotanical sampling has been undertaken. I will discuss the taphonomic issues and problems associated with specifically interpreting Epipalaeolithic plant material and I will examine the past and current approaches to addressing the missing evidence of this period and their implications for this study of plant remains from Kharaneh IV.

In the first instance, we must deal with the reality of depositional bias. How has the plant material made its way to the site? Preservation depends on the composition and structure of the environment that the plant is deposited in (Behrensmeyer *et al.* 2000; Gallagher 2014; Dieffenbacher-Krall 2007). Additionally, it is essential to consider that conditions such as sedimentation rates, temperature and moisture may have played a role in the plant material's journey to the site and resulting preservation (Beck 1989; Berg and McClaugherty 2008). Adding to this, we must deliberate on the animal and microbial activity that can also disturb and alter the chances of preservation (Pearsall 2000; Behrensmeyer *et al.* 2000; Birks 2007; Dieffenbacher-Krall 2007; Gallagher 2014). Humans also play a role in this process as the deliberate transport of seeds by humans, and the choice of which seeds to transport, needs to be contemplated (Dennell 1972), as does the probability of inadvertent transportation onto the site by humans, animals, wind, or even dung (Helbaek 1964; Miller 1984, 1997; Hillman *et al.* 1997).

Considering that bones survive the taphonomic processes better than plants, hunter-gatherer populations have, in the past, been classed primarily as hunters, ignoring the gathering aspects of their namesake. This preconception is often validated in literature and media with scenes of hunter-gatherer men hunting, or in the depiction of animal carcass preparation activities taking place near a hearth (Weiss, 2008). However, if we consider the evidence provided by modern ethnographic studies of hunter-gatherer

populations, it is quite clear that wild plants are widely used as a food source, especially in arid and semi-arid areas (e.g. Mandeville 2013; Wilcox 2012; Kislev *et al.* 1992; Weiss 2002). Turning to archaeological evidence, this also concurs with this idea of plant use. Specifically, when it comes to the Epipalaeolithic, the site of Ohalo II had the necessary taphonomic conditions (burning followed by waterlogging soon after abandonment) that allowed a full spectrum of plants to be represented and has clearly demonstrated that wild fruits, nuts and seeds certainly played a role in the early Epipalaeolithic hunter-gather diet (e.g. Kislev *et al*. 1992; Weiss 2002; Simchoni 1998; Snir *et al.* 2015).

As is the case with Kharaneh IV's plant remains, the majority of archaeological excavations have revealed botanical remains that have been preserved through carbonisation. However, waterlogging, desiccation and mineralization are also possible modes of preservation, but are particularly rare in the Southern Levant (Jacomet and Kreuz 1999; Renfrew, 1973; Dennell 1976; Hillman, 1981). At Kharaneh IV there are a select few seeds that have survived due to mineralisation, specifically *Lithospermum* sp. (see Shilito 2010 for further discussion of mineralisation in the case of *Lithospermum*), however, here I focus on carbonisation, as this is the predominant preservation mode of the plant assemblage at Kharaneh IV.

Carbonisation largely ensures plants remain resistant to damage, offering a decent chance of survival and preservation (Boardman and Jones 1990; Hillman 1981; Bryant 1989; Märkle and Rösch 2008; Gallagher 2014; Dieffenbacher-Krall 2007). Even more selectively, we should consider that for carbonisation to occur, the fire must be just the right temperature (what I like to call a 'Goldilocks' fire: not too hot and not too cold, but just right) for seeds to not be destroyed (Braadbaart *et al.* 2012; Boardman and Jones 1990; Hillman 1981). Carbonisation occurs when plant material is exposed to low (~500 °C) (Boardman and Jones 1990) temperatures in fires with a limited supply of oxygen and the plant's organic compounds are converted into charcoal (Boardman and Jones 1990). Specifically the combination of oxygen, temperature and time of exposure within the fire determine the threshold between allowing the seed to remain as a carbonised fossil and turning it to ash (Boardman and Jones 1990). Once carbonised a plant can survive under most conditions (Boardman and Jones 1990, Hillman 1981, Zohary and Hopf 2012, Styring *et al.* 2013).

Occasionally, entire settlements, structures or storage contexts are completely burnt, thus providing us with *in situ* examples of the plant based economy and the foods collected and valued by the inhabitants (e.g. Ohalo II: Kislev *et al*. 1992; Weiss 2002; Simchoni 1998; Snir *et al.* 2015). Plant material can become charred under deliberate or accidental conditions. Differential preservation is also a factor that we must consider, as the smaller, more delicate parts of plants may not survive the fire (Boardman and Jones 1900). The type or plant part (e.g. leaf, tuber, or seed) in combination with the cooking or preparation methods also determines the chances that a plant part has of coming in contact with fire, which may add or detract from the chances these plants might make it into the archaeobotanical record (Willerding 1971,1991). Considering some of the material studied here comes from varied contexts, i.e. not from inside hut structures, their presence may be random/wild rather than directly connected to food preparation or other activity. From this collection of samples, the best connection to cooking or preparation we can gain is from those taken from contexts associated with hearths.

The frequency of fire at a settlement may also play a role in what survives (Mallol *et al*. 2007, Colledge, 2001). At Kharaneh IV, this is of particular importance as we are dealing with many episodes of repeated or intensified periods of use. Foods that tend to be cooked in the coals of a cooking fire can become spoiled or over-cooked and may also be discarded into cooking fires. As Colledge (1991) noted, these consumption practices can play a major role in determining what is preserved. For example, for plants such as vegetables, tubers and other roots that are roasted directly in the fire or the surrounding coals, the whole item or forgotten/discarded fragments may only preserve as unidentifiable residues which tend to be overlooked during analysis (Hather, 1988, 1993 and 2000; Pryor *et al*. 2013). This scenario may account for the absence of clear macro-botanical evidence of tubers, or USO's, at Kharaneh IV as their potential presence is noted (Ramsay and Rosen 2016).

As we know from later agricultural examples, certain cereals often need to be parched during their processing to separate the grains for consumption (Nesbitt and Samuel 1996, 43-49). It is therefore not far-fetched to suggest that hunter-gatherers could have also practiced toasting techniques to aid in the extraction of food sources. If practiced, under these circumstances, it is plausible that accidental burning could have been

quite common. While we do not have large amounts of cereals present at Kharaneh IV, it is possible that some of these may have come in contact with fire via this method.

Confounding this further, Boardman and Jones (1990) demonstrated through charring experimentation on weed seeds, cereal grains and chaff that the absence of plant parts does not necessarily reflect their real absence in the past. It is also the plants' ability to survive after being exposed to fires that determines what remains (see also: Braadbaart *et al.* 2012; Braadbaart *et al.* 2004abc). Boardman and Jones (1990) investigated the likelihood of cereals and chaff surviving under varying conditions such as: wet/dry, different temperatures, varying lengths of exposure and in oxidising and reducing environments. They concluded, "the first components lost through charring are precisely those which are only rarely represented archeologically, and which are characteristic of early crop processing stages, i.e. straw and free-threshing rachis" (Boardman and Jones 1990). As Hillman *et al.* (1989) has pointed out, we must take into account potential gaps in the archaeological record and be realistic as the plants that survive provide only part of the picture of past diets. Hillman (*ibid*) continues to note that this becomes even truer when preservation is by charring, as all of the raw foods that may have been cooked by boiling methods are even less likely to come in direct contact with fire. Even if these foods managed to make their way into a fire, the chances that they would survive the charring in an identifiable form are very low.

In attempting the reconstruction of the environment or diet of the Kharaneh IV hunter-gatherers, any charred plant remains, especially those originating from hearths or storage contexts can provide us with relatively clear evidence of the plant-based economy and diet of the settlement. However, as noted previously, for the samples studied here, there is no evidence of any originating from a storage context. We do however have hearths and these results are noted and discussed in the upcoming discussion. As the lack of data for the Epipalaeolithic exemplifies and, according to ethnographic accounts, the short-lived nature of small domestic cooking fires made by hunter-gatherer groups results in very little preservation (e.g. Simms 1988; Jenkins *et al*. 2011). Colledge (2001) also noted that permanent sites with cooking area installations are more likely to produce characteristic representations of the repeated

activities that have been carried out there, whereas in the case of seasonal, pre-sedentary settlements, such as those in the southern Levant, successive occupation could mean that activity areas differ between visits.

7.2. Site formation and problems of interpretation

Once charred, a plant endures a string of taphonomic processes that can distort or change its appearance. Charred plant material in a hearth context will often be disturbed as the ash is spread around, or new fires are built; when the fire is repeatedly kindled in the same general area, smearing of the ashes increases and the centre of the fire drifts (Binford 1983; Mallol *et al.* 2007; Simms, 1988). Binford (1983) also noted that when a fire is used for roasting food, the constant fire tending, shifting and turning of food causes the ash and fire-cracked rock to be dragged away from the centre of the hearth. It is probable that these actions would add to the mixing and spreading of the ashes, charred material and some of the un-burnt material surrounding the fire (Mallol *et al.* 2007; Schiffer 1996, Simms 1988, Colledge 2001).

What is important to note here is that this spreading would further distort the dispersal and concentration of plant material, while also theoretically damaging or breaking the plant parts. One possible route to further information about the plants from the hearths would be to look at the phytoliths and calcitic ashes using micromorphological and phytolith analysis (Mallol *et al.* 2007; Matthews 2010; Piperno, 2006). Mallol *et al.*'s (2007) ethnoarchaeological study of sedimentary signatures of fires made by modern Hadza hunter-gatherers in Tanzania has begun to address how micromorphology can distinguish between natural and anthropogenic fires, estimate burning intensity, and identify which fuel types may have been used. This combination of ethnographic information and micromorphological data contributes to our understanding of spatial organisation, site use as well as the duration of occupation. For Kharaneh IV, phytolith studies are on-going (e.g. Ramsay *et al.* 2016, Ramsay and Rosen 2016).

Simms's (1988) study of the archaeological structure of a Bedouin camp in Jordan concluded that the use of hearths to infer the broader aspects of overall past diets is problematic. Simms's study, supported by Schiffer (1996) and O'Connell *et al*.'s (1991) findings on site formation, suggests that activity areas are routinely swept. Thus, Simms suggests that the hearth contents represent only the last day or two of

occupation (*ibid*). Simms also compared hearths to the use of coprolites in the reconstruction of past diets, pointing out that they should be seen as a precise source about a specific meal rather than a general indicator of diet (see also Fry, 1977). This repeated cleaning of the hearths or hearth areas alters the composition of primary refuse as it is often moved to secondary refuse dumps located away from the living area, at the edge of the activity area (Schiffer 1996, O'Connell *et al*. 1991, Simms 1998). Once deposited, plant remains will also likely undergo varying levels of post depositional movement and or destruction. Onsite activities, such as the movement of people, scavenging by animals and the re-deposition and mixing and moving of waste all add to the distortion of information (see also Balme and Beck 2002). In addition to this, bioturbation or soil mixing (Wood and Johnson 1978 call it pedoturbation) may alter the fragile components of archaeobotanical assemblages.

At Kharaneh IV, there are many occupational surfaces or lenses and the intensive deposition of artefacts, but also gaps that may represent periods of disuse. These varying stratigraphic layers may also indicate various events or phases where site use changed, thus the post depositional reality may be different for each layer. However, here in this study, no notable differences in the degree or mode of preservation between these events was noted, but further work in this area (more samples), may reveal variation. It is these above mentioned processes that should remind us that, in the lab, we need to recognise that the deposits we are assessing are likely the result of a 'mixed bag' of processes (Schiffer, 1987, 266) and this mixing diminishes our ability to identify behavioural activities (Jones 1991).

Due to the taphonomical and preservation issues discussed above, we are left with an absence of certain foods which do not survive these processes and that could have played an important role in the inhabitants' diets. These foods often consist of soft tissues, such as tubers and the flesh of fruits, that do not survive carbonisation as well as grains do. The fact that most identification keys and manuals only refer to seeds has also contributed to there being very few studies on these softer plant parts.

7.3. Damaging recovery methods?

The retrieval process of archaeobotanical remains (often flotation) lends a bias in the sample composition of seeds (Jones 1990). It is likely that some remains are destroyed

during the retrieval process or are lost if appropriate sieve sizes are not used. The possibility of destroying or losing other fragile plant parts while sieving them through a stack of sieves also leads to a potential bias (Hosch and Zibulski 2003). The sieves can further damage the fragile plant material and there is also the chance that too large, or an inappropriate sieve sizes may allow the loss of informative small seeds. This is especially true when dealing with already sparse data and the often small size of wild seeds recovered from excavations.

I personally experienced a clear example of this while working on the Natufian site of Shubayqa (just 40km north east of Kharaneh IV) in the autumn of 2012 when I noticed that individual tubers from a large storage context/cache we had found were disintegrating into tiny fragments the moment they came into contact with the water. Following this discovery, we implemented a dry sieving technique prior to flotation in order to retrieve as many of these 'water soluble' plant remains as possible. Therefore, I firmly believe it is imperative to consider the importance of having archaeobotanists on site during excavation so that they can monitor or undertake the flotation themselves in order to diminish the chances of destroying valuable evidence that has, up until excavation, survived the test of time.

Chapter 8. Archaeobotanical Discussion and Conclusions

8.1. Introduction

The primary objective for this chapter is to contextualise the first ever archaeobotanical results from the site of Kharaneh IV, which were presented in the previous chapter. With the aim of providing new archaeobotanical data outlined in the introduction of this thesis, here I provide a discussion of these new archaeobotanical data and how they provide us with a better understanding of the taxa and environmental conditions present at Kharaneh IV. By examining the evidence from across the site and its stratigraphic zones, a greater understanding of the local environment and plant resources available to the hunter-gatherers of Kharaneh IV is gained. I then compare, contrast, and discuss Kharaneh IV in relation to the temporally similar sites from the Southern Levant that were reviewed in the archaeobotanical background section in order to gain a better understanding of how Kharaneh IV fits into the Epipalaeolithic. I also touch on the 'missing' plants, i.e. those that users of the site may have had access to, according to existing publications of archaeobotanical and ethnographic information, but that do not appear in the archaeobotanical record of Kharaneh IV. Lastly, I will discuss and address the challenges related to the analysis of the material from Kharaneh IV, specifically touching on how well we can reconstruct the environment from archaeobotanical remains (e.g. limitations of species identifications and taphonomic and temporal challenges).

8.2. What does the plant community suggest the environment was like?

The diversity and abundance of taxa can, potentially, provide insight into the environmental conditions at Kharaneh IV and how they changed throughout occupation. For example, times of water stress should result in lower density of some drought intolerant seeds, due to decreased productivity, and lower diversity (Jackson and Overpeck 2000). In regard to the latter, arid conditions should act as an environmental filter that removes species that require wetter conditions (Weiher *et al.* 1998). Examining the density of seeds and taxa from Kharaneh IV showed that seed density was lowest in the deepest and shallowest stratigraphic zones, possibly suggesting lower productivity in the surrounding environment. Diversity was also

lower in Area A, especially in A1 (see Figure 2.3 for dates and cultural phases), which was the final stage of occupation, possibly suggesting harsher conditions during this time (Figure 6.19–Figure 6.21). However, such interpretations must be made cautiously as in many cases there is a lack of statistical significance in the diversity trends, especially in relation to the balance of wet and dry species, likely because of low statistical power. The sparse nature of Epipalaeolithic archaeobotanical data justifies cautious interpretation of apparent trends, despite a lack of formal statistical significance, provided they are considered suggestive at most. Other factors may also confound these purely ecological interpretations, such as differing levels of use of the site which could produce changes in overall density that are unrelated to environmental conditions (e.g. Simms 1988). Yet, we must note that these factors may operate together: harsher conditions and lower productivity should produce reduced site use by humans. As conditions worsen and resources become scarcer, hunter-gatherers may have abandoned sites in favour of other areas with more plentiful resources, as predicted by foraging theory in ecology (Charnov 1976), or they may suffer increased mortality rates and/or lower birth rates, decreasing population size. These non-mutually exclusive responses to harsher environmental conditions and lower resource availability would lower site use intensity, reducing the amount of evidence of human use and occupation in the archaeobotanical record. Below, I outline the plant community of each stratigraphic zone and what it can (and cannot) tell us about the environment of Kharaneh IV during that time.

8.3. Discussing the evidence by stratigraphic zone

Stratigraphic Zone B3

This zone is the deepest stratigraphic zone at Kharaneh IV (Figure 2.3), and has been associated with the cultural phase of the Early Kebaran (Maher *et al.* 2012). Here our broader perspective is restricted, as there are limited samples and these samples originate from just one square, P1, and three loci. Despite these limitations, this zone has the highest density of seeds per litre of sampled soil at Kharaneh IV. This high density might arise from improved preservation due to the depth of these samples. In contrast to the high density, B3 also has the lowest diversity of taxa for the site. Preservation may also have played a role in this low diversity, as preservation conditions could have favoured certain species over others, thus limiting what persisted (see taphonomic considerations in Chapter 8). Also, the rarefaction analysis

suggests that the apparent low diversity may simply be an artefact of the small sample size. Another factor to consider here could be the lower frequency or intensity of use of the site at this early stage of occupation. If fewer people were visiting the site, then their ephemeral use would have made less of an impact on the area, thus reducing the amount of plants collected, moved or stored on the site and reducing the chance of preservation.

Analysing the ecology of taxa from B3 reveals it was dominated primarily by taxa like Chenopodiaceae spp., *Atriplex* sp., and *Nitraria Schoberi,* suggesting a predominantly dry environment. However, the presence of quite a few varied taxa and some wet taxa (in particular the possible Cyperaceae cores), indicate that it was not uniformly dry and that there were either fluctuations between wet and dry or spatial heterogeneity comprising wet and dry microhabitats.

Stratigraphic Zone B2

Zone B2 is still in the Early Kebaran cultural phase (Maher *et al.* 2012) (Figure 2.3), and the evidence is a bit broader as there are 8 squares and a total of 25 loci present in this zone. The densest square is AW74. B2 has, by far, the most diverse taxonomic assemblage, but it also has the second lowest density of seeds on the site. However, this lower density only represents a difference of less than 2 seeds/L in comparison with the other zones.

The ecology of this zone suggests a varied habitat. In Figure 6.40 there is evidence that varied taxa dominate. However, this is nearly matched by the presence of both wet and dry taxa, suggesting less extensive, or intensive, dry conditions compared to Zone B3. Again, there were a few Cyperaceae spp. present, suggesting the presence of standing water during at least one point throughout the year, which is conceivable during short-lived seasonal rains. These results do not allow for precise inferences regarding the environment during the time encompassed by B2 as the large number of varied taxa could have tolerated habitat fluctuations and spatial variability in moisture availability. However, overall these data hint at a move toward wetter conditions, compared to Zone B3. This is consistent with other evidence of more intense human use during this time as this zone coincides with a higher frequency of floors and occupational surfaces (see Figure 2.3 and Maher *et al.* 2012), though this also raises

the possibility that increased use led to biased exploitation of wet taxa, reducing the apparent dominance of dry taxa and thus the apparent extensiveness, or intensity, of dry conditions around the site.

Stratigraphic Zone B1

This Zone is the surface level of Area B and represents the Late Kebaran stage at Kharaneh IV (Maher *et al.* 2012) (Figure 2.3). Here there is evidence of the highest densities of seeds, drawn from 6 Squares and 4 Loci, with the seed-densest squares being P3 and AY74. However, diversity was intermediate, in comparison with the other zones.

Again the ecology of this zone is mixed. From an ecological perspective, dry species have the highest density here (Figure 6.39) compared to wet and varied species, as in the previous two zones, suggesting a substantial amount of dry habitat. The highest density of the dry-preferring *Atriplex* sp. is in this zone (Figure 6.20), which again adds evidence towards an arid environment. However, we must proceed with caution here as these concentrations of seeds may be due to the deposition of entire seed heads (which could contain 100s of seeds), which would cause a bias. In contrast, varied habitat species dominate the diversity measures, and the diversity of wet species is higher than dry (Figure 6.40), suggesting that while overall the habitat is relatively dry, there may be relatively more wet habitats in this area than in B2. We again have the presence of the Cyperaceae family members, indicating the presence of standing water at some point during the year (see Colledge 2002) within some proximity to the site. Other species present also indicate preferences for varied habitats, which again suggest the habitat was not uniformly dry.

Stratigraphic Zone A2

Moving upwards in time and across space to Area A, this stratigraphic zone brings us into the cultural phase of the Geometric Kebaran (Maher *et al.* 2012) (Figure 2.3). This zone has 13 Squares and 4 Loci represented, with AQ36 and its neighbouring square of AP36 being the densest squares. This stratigraphic zone was dense and diverse, offering us the second most seed taxa diversity, as well as density, at Kharaneh IV.

The ecological generalisation of this zone suggests a varied habitat with dry, wet and varied taxa all present. However, here there is the highest density of varied taxa (literally off the chart), accompanied by the highest density of dry taxa for all of Kharaneh IV (Figure 6.39 and Figure 6.40). In contrast to B2 and B1, we again see relatively fewer wet taxa than dry taxa. This, perhaps, hints that this period of occupation was drier. However, we are still faced with the presence of some wet taxa and a high proportion of taxa that can inhabit wet or dry environments, making precise environmental inferences difficult.

Stratigraphic Zone A1

This stratigraphic zone lies within the Geometric Kebaran (Maher *et al.* 2012, Figure 2.3), and tells us about the final stage of occupation at the site. Here ,there are 13 Squares and 9 Loci represented with AP36 as the densest square, likely due to the presence of a hearth. While having the second lowest diversity of taxa, this stratigraphic zone offered us the lowest densities of seeds, which is perhaps due to it being so close to the surface, having undergone the most recent deflation (Garrard *et al.* 1988). The low density and diversity would be consistent with conditions of low productivity and a strong environmental filter (Weiher *et al.* 1998; Keddy, 2010; Algar *et al.* 2011), especially given the extreme low density of seeds from wet taxa. However, as a recurring theme, the dominance of varied species makes inference difficult and, while there is evidence consistent with an overall drying out as there are more dry taxa than wet, their relative proportions are not obviously different from the earlier A2 Zone.

Summary

Overall, the ecological analysis of Kharaneh IV provides a general overview of conditions but at relatively low ecological resolution and with significant limitations. The mix of dry, varied and wet taxa at all time periods is consistent with Ramsay and Rosen's (2016) mosaic landscape model for Kharaneh IV, which suggests that by settling in the wetlands, the inhabitants would have had access to the dependable food storage repository the surrounding wetlands provided, which would have in turn allowed them to undertake riskier foraging forays beyond the wetlands (Ramsay and Rosen 2016). The evidence for taxa that prefer wet and/or dry environments throughout the site is perhaps obvious, as a completely arid environment, with no

access to water, would be unlikely to support human habitation. Changes in density and diversity of wet and dry species are suggestive of environmental change, but the specificity and reliability of these inferences is limited by small sample sizes, taphonomic factors, potential confounding of human-use biases, and especially the low taxonomic and ecological resolution of the data. Within families, and even genera, species can vary greatly in their microhabitat preferences, and even within species, hydric niches can be broad (Jackson and Overpeck 2000). This lack of habitat specificity, coupled with difficulties in identifying poorly preserved, sparse Epipalaeolithic remains to low taxonomic levels (e.g. species), makes inferring specific environmental conditions and the extent of environmental change from the taxonomic composition of plant communities difficult. Thus, the inferences presented here should be considered suggestive at best and highlight the need for additional, supplementary lines of evidence for environmental conditions during the occupation of Kharaneh IV.

8.4. Comparing Kharaneh IV with other Southern Levant Epipalaeolithic sites

Here I contrast and compare the results from Kharaneh IV with the sites detailed earlier: Kebara Cave, Ohalo II, Wadi Jilat 6, Wadi Hammeh 27 and the Hayonim Cave.

Kebara Cave, Mt. Carmel

As discussed in Chapter 4, Kebara Cave, Mt. Carmel, is an earlier, Middle Palaeolithic site (Lev *et al.* 2005) that has been included in the comparison with Kharaneh IV because it offers a rare glimpse into the foraging/subsistence and plant exploitation in the Levant in the period leading up to the Epipalaeolithic. Kebara Cave is perhaps best known archaeobotanically for its high density of legumes (78.8% of the identified seeds were from the legume family; Lev *et al.* 2005). On this front, Kharaneh IV has not yet provided us with any significant evidence for legume exploitation, although one large and one small Leguminosae were found. A paucity of grass seeds (just 10), a few of which have been identified as *Hordeum spontenaum*, have been uncovered from Kebara Cave (Lev *et al.* 2005). The Kharaneh IV record is similar, with just 13 fragments identified as *Hordeum* sp.. Diversity of remains is also similar between the sites, with a total of 51 identified taxa from Kebara Cave (Lev *et al.* 2005), compared to 46 taxa from Kharaneh IV. Kebara Cave is believed to have

been occupied for most of the year with the exception of high summer abandonment when it is thought the inhabitants would move to higher altitudes (Lev *et al.* 2005, also see Valla, 1998). While no specific archaeobotanical seasonality studies have been done as part of this study (due to the nature of the samples), there is zooarchaeological evidence, based on gazelle remains, of year round use of the site (Jones 2012), suggesting similar, but not identical, usage patterns between the sites, with the key difference the lack of year round occupation at the earlier site.

Ohalo II

With more than 90,000 plant remains identified (including 142 taxa; Kislev *et al*. 1992, 2002a, 2002b; Simchoni 1998; Weiss 2002, 2008; Nadel *et al.* 1994; Snir *et al.* 2015), Ohalo II remains the most prolific and intensely studied archaeobotanical material for this time period in the Levant. There are an impressive number of taxa identified to species level (Weiss *et al*. 2008), to which Kharaneh IV, with 2985 identified seeds, currently pales in comparison. However, the unique nature of the preservation process at Ohalo II (the combination of burning and waterlogging), and with no specific details on the total volume of soil that produced the 90,000+ plant remains, Kharaneh IV appears to have a comparatively high density of plant remains. The density of seeds recovered at Kharaneh IV from the 95 samples and just 3086.4 L of soil is impressive, totalling 2985 identified seeds and 2181 fragments of plant material; future work will unveil considerably more. The material presented here represents only the first few samples to emerge from Kharaneh IV, and there remains tens of thousands of litres of soil to be floated, including the contents of the hut structures (Maher *et al.* 2012), which are likely to produce the most interesting archaeobotanical material for this time period.

The presence of *Nitraria schoberi* at both Ohalo II and Kharaneh IV deserves discussion. These stones/seeds are edible and have been used by the Bedouin to make syrups and jams (see Mandeville 2012 and Seed Catalogue (Appendix 3) for more details regarding ethnographic use). It is conceivable that these small fruits would have been an attractive food source to the local inhabitants at both sites and could have been present in their local food pantry. If the ethnographic parallel of making these fruits into syrups and jams was used, it could have extended the preservation

period, as could drying the fruits (like raisins), allowing them to be stored for the winter months.

An obvious difference in the assemblages recovered from Ohalo II and Kharaneh IV is in the grasses. While very few large seeded grasses were found at Kharaneh IV (I have identified a total of 13 *Hordeum* sp. fragments), Ohalo II leads the way in early finds of *Hordeum spontaneum* (wild barley) and *Triticum dicoccoides* (wild emmer) (Kislev *et al*. 1992, 2002a, 2002b; Simchoni 1998; Weiss 2002) suggesting that exploitation of these as a food source may have been greater at Ohalo II than Kharaneh IV, though the incomplete and on-going processing of the whole site at Kharaneh IV may also contribute to the lack of large grass remains.

At Kharaneh, I did not identify any evidence of plant processing by-products such as rachis, glume or spikelet bases which were present at Ohalo II (Weiss *et al.* 2004b, Snir *et al*. 2015). However, we do have grindstones present (analysis is on-going) at Kharaneh IV. The absence of chaff may be due to preservation failures, or, more likely, the origin of the Kharaneh IV samples studied (deposits, outside floors and external hearth areas). Caches of seeds at Kharaneh IV are non-existent thus far, also likely due to the samples origins, which were not associated with any structures. I suspect that with more sampling, particularly within or near the huts, we are likely to recover more large-seeded grasses. Additionally, caches of lithic tools have been uncovered at Kharaneh IV (see Maher *et al.* 2012). As caching of supplies/tools was practiced at the site, caching of food is also possible. The presence of large-seeded grasses, in particular the *Hordeum* sp., suggests that these may have played a role in the diet of the inhabitants, similar to the Ohalo II's inhabitants (see Weiss *et al.* 2004b). However, at this point, this remains an untested hypothesis based solely on the presence of a few seed fragments from Kharaneh IV.

Ohalo II also presents us with evidence of *Pistacia atlantica* fruit/nutshell fragments. In contrast, at Kharaneh IV, where there is only anthracological evidence for *Pistacia* sp. charcoal in Area B and no evidence of fruit or nutshell remains. The anthracological findings suggest that *Pistacia atlantica* could have been brought to the site as fuel. However, if the inhabitants had access to the wood, they likely had access to the fruit as a food source, as well as for other uses, such as resin (Colledge 2001).

While there is no direct evidence of consumption from Kharaneh IV, it seems unlikely the inhabitants would have ignored other uses for this plant given they were already utilising it for fuel, so we can perhaps consider that they may have been consuming the nut/fruit at the site of origin, away from Kharaneh IV, and only transporting the wood to the site as fuel or for construction/tool use. Matthews (2016) has also discussed a variety of factors that can be considered here for Kharaneh IV, regarding why *Pistacia* may be missing from a site. Namely, it is possible that the nuts may have been roasted/toasted to ease access, preservation or taste, and after the nut had been extracted, the shells were used as a highly combustible fuel (Hillman 1984; van Zeist *et al.* 1984). It is possible that none of these shells have survived in the archaeobotanical record at Kharaneh IV, or we have yet to sample a fire pit/hearth where this activity may have taken place.

Wadi Jilat 6

In contrast to Kharaneh IV's 2,985 identified seeds, there are just 283 seeds identified to taxa/type and just 19 taxa/identification classifications from Wadi Jilat 6. Due to the low numbers of unidentified items/taxa, Colledge (2002) has hypothesised that preservation issues may have played a role in the low numbers of remains recovered from Wadi Jilat 6, and that conditions did not favour most of the potential material (Colledge 2002). The higher density and diversity of seed remains extracted from Kharaneh IV, in comparison to Wadi Jilat 6, highlight the potential importance of Kharaneh IV to the archaeobotany of the Epipalaeolithic Levant.

Given that Wadi Jilat 6 is the nearest (just 25 km) coeval site to Kharaneh IV, it is surprising that there are very few archaeobotanical similarities between the two sites. Various factors such as erosion processes and occupation patterns/periods of intense use (Garrard and Byrd 1992) could contribute to why the abundance and preservation at Wadi Jilat 6 might be so different than at Kharaneh IV. It is possible that the functions of the site, or the sampled areas, served different functions than those sampled from Kharaneh IV. Thus, despite the sites being so close in proximity and time, it is possible that very different practices took place within them.

Wadi Jilat 6 offers a different range of species, with very few crossovers with Kharaneh IV, with the exception of *Atriplex* sp., Chenopodiaceae spp., Compositae

Kernels, and a few Cyperaceae, which make up the entire list of species that occur on both sites. Prominent species from Wadi Jilat 6 that were not found at Kharaneh IV include: cf. *Bromus* sp., *Echinaria* sp., cf. *Stipa* sp., *Schoenus nigricans*, cf. *Sophora*., *Verbascum* sp. (Colledge 2001). However, at a coarser taxonomic resolution, i.e. family, there are similarities in that both sites have very high counts of Chenopodiaceae, which include taxa such as *Atriplex* sp., and are associated with, and typical of, steppe-desert environments. However, a heterogeneous environment at Wadi Jilat 6 also seems likely as Colledge (2001) concluded that the presence of Cyperaceae (sedges) indicated the proximity of the site to water. This is consistent with the presence of Cyperaceae at Kharaneh IV and with the hypothesis that Kharaneh IV was situated within or near wetlands at least during much of its occupation (see Chapter 3 and Jones *et al.* 2016). Another explanation for the difference between Kharaneh IV and Wadi Jilat, could be attributed to the Azraq Basin being a mosaic of ecological habitats (Ramsay and Rosen 2016), which again reinforces the importance for archaeologists to consider a very local perspective when dealing with hunter-gatherer sites.

Wadi Hammeh 27

Kharaneh IV provides us with a significantly richer dataset than Wadi Hammeh 27 (Colledge 2001). Wadi Hammeh 27 supplies only 19 taxa categories and 102 identifications (see Table 4.5), in contrast to Kharaneh IV's 46 taxa identification categories and 2,985 identifications. With so little data for comparison, there are few generalisations that can be drawn. Nonetheless, there are several differences worth mentioning. Interestingly, at Wadi Hammeh 27, there are *c*. 3 *Hordeum spontaneum* rachis internodes from an unknown context (Colledge 2001), which are, as mentioned above, absent from Kharaneh IV. However, at Wadi Hammeh 27, it is quite possible that the presence of the rachis may be completely natural as the site is located within the species' natural distribution range (Zohary *et al.* 2012). *Hordeum spontaneum* (wild barley) is well adapted to arid regions and extends into the Mediterranean region (Wilcox 2005). Wadi Hammeh 27, like Wadi Jilat 6, also presents us with evidence of *Pistacia* sp. fruit/nutshell remains (Colledge 2001). As discussed above, while no identified fruit/nut shell fragments were recovered at Kharaneh IV, there is anthracological evidence of *Pistacia sp.* wood from Area B,

which could have been a fuel source and possibly also used as food or a source of resin.

Hayonim Cave

Hayonim Cave is the latest (most recent) Levantine site comparable to Kharaneh IV, but there is little to compare with respect to archaeobotanical material. As mentioned previously in Chapter 4, despite systematic wet sieving and some flotation, the archaobotanical assemblage from Hayonim Cave consists of a grand total of two partial *Hordeum spontaneaum* grains, unidentified numbers of almond (*Amygdalus communis*) fragments, corroded cf. *Pisum* sp. seeds; and fragments of *Lupins pilosus* (Hopf and Bar Yosef, 1987). For the purpose of this thesis no further discussion or analysis between these two sites is justified at this point, however, if and when, more data are available then this comparison could be revisited.

Summary

Overall, the findings from Kharaneh IV are consistent with the broader regional archaeobotanical picture from the Epipalaeolithic Levant. The site does stand out in terms of the density and diversity of the archaeobotanical remains, which far surpass those from any other site, other than Ohalo II, which has a far more complete analysis. The low numbers of large-seeded grasses, and a lack of rachis, glume or spikelet bases, are notable as these are present at several other sites in the region. The lack of direct evidence of consumption of *Pistacia* sp. also sets Kharaneh IV slightly apart, but indirect evidence would suggest this was a potential food source for its inhabitants. The lack of caches from Kharaneh IV likely reflect the location of available samples for analysis in this dissertation, and highlight the potential of the site to provide greater understanding of Epipalaeolithic archaeobotany when further material from in and around the hut structures become available.

8.5. Food and diet at Kharaneh IV: an incomplete picture

Here, I discuss the archaeobotanical remains from Kharaneh IV in terms of what they can tell us about food and diet of the hunter-gatherers that used the site. This will be presented in general terms as several factors make detailed reconstruction of diet at the site impossible. Even though Kharaneh IV is relatively dense in terms of

archaeobotanical remains compared to other sites, sampling is still sparse. Moreover, the low taxonomic resolution that was possible during identification means that I cannot always conclusively state whether remains would have acted as a food source. Even if we did know the exact species, the existence of plant remains on a site does not directly indicate that humans consumed the species as food. Particularly when dealing with hunter-gatherer sites, direct evidence of food use can be extremely difficult to identify unless we have access, and can directly link the plant remains, to human coprolites, storage containers or cooking pots. Lastly, the lack of seed caches could suggest little storage on site. However, this is probably due to the unavailability of samples within or near the hut structures, which might be more likely to contribute reliable dietary information.

As discussed earlier in the introduction to this archaeobotanical section, taphonomic barriers prevent us from assuming that the absence of a species from the archaeobotanical record is an indication that it did not exist or was not used onsite. Many food sources are not detectable in archaeobotanical samples because they are never, or rarely, cooked. This suggests that the plants recovered from archaeological sites only represent part of the dietary picture (Hillman 2002; van der Veen 2007). The likely missing candidates are things like soft fruits, foods which may have been consumed off-site, fresh soft leafy foods, and young shoots and roots which have very little chance of being charred, or surviving charring in an identifiable form. This expectation is bolstered by experimental, ethnographic and ethnobotanical evidence that has helped shed light on the use of raw plants by the Bedouins in the Levant (Zohary 1973; Bailey and Danin 1981; Musil 1928, Mandeville 2011). In Bailey and Danin's (1981) account of the Bedouin plant use in the Sinai and Negev, they note that most of the plants used are ones that can be eaten without cooking; similarly, Musil (1928) recorded a number of species that are eaten raw by the Bedouins.

Here I synthesize the available information on which taxa identified from Kharaneh IV could have been used as food sources. Despite the above caveats, these new data, when combined with the regional (El-Asawi 1996, 1985; Al-Eisawi and Hatough 1987) and historical (e.g. Nelson 1973; Monfort 1965; Billet, 1965; Townsend *et al.* 1965) vegetation information allows us to infer some aspects of the dietary resources the users of Kharaneh IV had access to. Considering the limited edible resources

uncovered from Kharaneh IV, I also consider those foods that are likely missing from the archaeobotanical record and how these might relate to the data that we do have to provide an overall picture of potential food resources the inhabitants may have accessed.

Knotweeds and sedges

Starch-rich foods would have been available from local wetland species such as the knotweed: *Polygonum cf. salicifolium* (see: Appendix 3) or the presence of sedges such as the *Scirpus*, whose presence at Kharaneh IV is indicated by phytoliths (Ramsay and Rosen 2016; Ramsay *et al.* 2016), but was not found in the charred plant reamains. Other tubers and tap roots may have been available, but did not preserve in the archaeobotanical record. Nutlets may have arrived on site in various ways. Firstly they may have arrived mixed in with, or still attached to, plants that had been collected nearby for use as material for hut thatching or floor coverings/matting, rather than food. Secondly, although only a single nutlet from this general category was present (identified as *Polygonum cf. salicifolium*), it may have arrived on site as a potential food source. While we cannot be sure how such nutlets would have been prepared and eaten, we do know that the available bulbs and nutlets would have been at their highest caloric concentrations during the winter (Hillman 2000, Hillman 1989; Hillman *et al.* 1989) and, as Hillman has suggested in his studies of Abu Huyera, they could have offered a reliable food source as they are naturally stored *in situ*, growing in-ground during winter (Hillman 2000, Hillman 1989; Hillman *et al.* 1989).

The hunter-gatherer Egyptian site of Kubbaniya offers an archaeological parallel where consumption of these nutlets was confirmed by the presence in human coprolites (Hillman *et al*. 1989). Additionally, in North America there are examples from two cave sites in Nevada that point toward hunter-gatherer use of nutlets as food: the Lovelock cave, where human coprolites contained *Scirpus* sp. (Napton and Heizer 1970), and the Hidden Cave (Thomas 1984), where a cache of nutlets was found. We also have comparatively modern ethnographic evidence in the United States of the Lakota Sioux using the flour of parched *Scirpus* spp. to make griddle cakes (Rogers 1980). Additionally, in California, there is also an example of the Cahuilla people making an edible mush out of *Scirpus* flour (Bean and Saubel, 1972).

Chenopodiaceae

The seeds of chenopods are present throughout the samples extracted from Kharaneh IV. It should be noted here that, although they are relatively abundant, abundance should be viewed with discretion as each of these plants can produce thousands of seeds.

We cannot say definitely whether chenopods were eaten at Kharaneh IV. However, there is ethnographic evidence of various species of chenopods playing a role in hunter-gatherer diets, particularly from North America. There are examples of chenopods being used particularly during the autumn and winter months (Hillman 2000). Examples of these include the use of *Suaeda suffruticosa* by the Cahuilla people (Bean and Saubel 1972. 45), along with the use of iodine bush (*Allenrolfea* sp.; Felger and Moser 1985), Mexican fireweed (*Kochia scoparia*), and *Atriplex* sp. (Rogers 1989). The new leaves of *Atriplex* are also edible (Mandeville 2012). Thus, while we cannot say for sure whether chenopods were part of the diet at Kharaneh IV, they were certainly available to the inhabitants and evidence from hunter-gatherer sites from elsewhere in the world certainly suggest they are a feasible food source.

Grasses

Grasses are a potential food source at Kharaneh IV. This is an area that deserves much more investigation with the future analysis of more samples from Kharaneh IV, in particular from the hut structures and associated loci. In Zone B3 (and for the site as a whole), the larger cereals found at Kharaneh IV are present in the form of fragments (and therefore excluded from much of the quantitative analysis here). *Hordeum* sp. is present, as well as some large fragments of unidentified Gramineae. In addition to the *Hordeum* sp., it is likely that the fragments classed as Gramineae Large and Gramineae Medium also represent the presence of accessible wild cereal resources at or near the site.

Unlike at Ohalo II, where the presence of rachis, glume and spikelet bases has been taken as evidence for food processing on site we found no chaff at Kharaneh IV. Thus, there is no evidence of the purposeful collection of any grasses (Gramineae), or of processing on site. However, given the presence of a number of small seeded

grasses, and a few larger seeds (such as the *Taenetherum* sp., and the fragments of wild barley, *Hordeum* sp.), it is possible to suggest that the collection of wild cereals as a means of subsistence was likely. Wild stands of cereals must have existed within a reasonable distance to the site, given the presence of some fairly large grained Gramineae. Even today, Bedouin travel to the area around Kharaneh IV and spread seeds in the autumn with the intention to return in the spring with their livestock to graze on the early greens after the winter rains. In 2012, I personally observed local Bedouin shepherds spreading the seed in what seemed like a desert landscape. Upon asking them what they were doing, they explained that in the autumn, they scatter the seeds and after the winter rains, the grasses bloom and the shepherds then return with their sheep to graze on the briefly green grass.

Fruits/Nuts

There is limited evidence of fruit and nut remains from Kharaneh IV. *Pistacia* sp., as discussed above, is present in the anthrocological record and could have been used for food as well as fuel, an inference bolstered by the presence of *Pistacia* nut/shell remains from Ohalo II (Kislev *et al*. 1992; Weiss *et al*. 2004b) and Wadi Hammeh 7 (Colledge 2001). The presence, at Kharaneh IV, of *Nitraria schoberi* offers a glimpse into an additional available food source. There is modern, ethnographic evidence of *Nitraria schoberi*'s use by the Bedouin, who collected and ate raw, or processed these salty, sweet fruits by boiling them down into a sort of jam (Mandeville 2012). There is also archaeobotanical evidence of *Nitraria schoberi's* presence at Ohalo II (Kislev *et al.* 1992), suggesting it may have been used widely throughout the region. Although not present in our samples, based on Nelson's (1973) and Al-Esawi'a (1996) records of modern wild fruits that grow in the Azraq Basin today, wild grapes, figs, fruits of wild capers, yellow hawthorn, Syrian pear and wild prunes could have been available; wild grapes also are reported from Ohalo II (Kislev *et al*. 1992; Weiss *et al*. 2004).

Truffles and fungi

Truffles and fungi are not evident in the Kharaneh IV assemblage, but they may still have been a potentially important food source. Musil (1978)) described the methods of truffle hunting done by the *Rwala* Bedouins, which provides them with food and a

commodity to sell in markets. Hillman (1996) also mentions fungi as one of the key missing items from the archaeobotanical record.

Tubers and parenchymous tissues

The previous work of Hather (1988, 1993, 2000) established cellular morphology and diagnostic techniques, typically using a Scanning Electron Microscope (SEM), to help identify, recognise and classify parenchymous tissues of vegetative storage organs. Colledge (2001) was very optimistic about the implications of being able to identify roots and tubers, hoping that this would address the imbalance of interpretations based solely on assemblages of charred seeds. However, little subsequent work has been done (but see, for example, Paz 2001 and Wollstonecroft *et al.* 2008) and most archaeobotanists still tend to group all parenchymous tissue into one category and simply note its presence. The recent work of Pryor *et al*. (2013) outside the Levant has renewed efforts to "develop the neglected methodology of identifying preserved soft plants". Pryor *et al*. (2013) also importantly called for further experimental charring of parenchymous tissues in order to expand the dearth of photographed reference material that can be used for comparison with archaeological material. Unfortunately, despite being rather hopeful at the outset of my analysis that Kharaneh IV would yield substantial evidence of tuber exploitation, Kharaneh IV is yet another site with merely a few millilitres of tuber like/parenchymous tissue fragments recorded. With less than 30 ml of small fragments found throughout the site, the idea of further analysis was abandoned. However, as noted above, this type of charred tissue can be extremely sensitive to water and may not survive flotation.

Summary

Together, the evidence from Kharaneh IV in terms of food resources provides a view that is consistent with the broader regional context and nearby sites. However, the relatively sparse sampling and lack of availability of samples associated with hut structures limit the possible inferences and may be responsible for several notable absences, especially in terms of cereal chaff and food caches. Other archaeological evidence, such as the presence of grindstones (Maher *et al.* 2012) which suggest food processing, and anthracological evidence of *Pistacia,* can help fill in the gaps in the current seed remains, as can ethnographic evidence. However, additional sampling is

unlikely to uncover complete dietary information, as many foods will escape preservation (Hillman 2002) and be forever missing from the archaeobotanical record.

8.6. Conclusion

The archaeobotanical data and analysis from Kharaneh IV conducted here provide as many questions as they do answers in relation to both environmental and dietary reconstructions. A common theme arising from both branches of enquiry is that there are substantial inferential limitations linked to sparse sampling, identification, and taxonomic and ecological resolution. Clearly, all answers cannot lie in the seed remains alone, but coupled with other archaeobotanical information (e.g. phytoliths; Ramsey *et al.* 2016, Ramsey and Rosen 2016), geological investigation (Jones *et al.* 2012, 2016), and archaeological finds (Maher *et al.* 2012) from Kharaneh IV, and a comparative approach with neighbouring sites, a more complete Epipalaeolithic picture both of environmental and dietary variability in the Azraq Basin can be drawn.

Chapter 9. Tracking Water Stress at Kharaneh IV: A New Application of Stable Carbon Isotopes

9.1. Introduction

As outlined in the introduction to this thesis (Chapter 1), as well as in the environmental (Chapter 3) and archaeobotanical (Chapter 4) chapters, reconstructing water access is a major aim of this research and essential to furthering our understanding of the site formation and abandonment of Kharaneh IV. This chapter addresses this aim by using stable carbon isotopes to reconstruct water stress throughout occupation at Kharaneh IV. As noted in the archaeological introduction to the site, radiocarbon dating has placed the occupation of the site between 19,830 and 18,600 BP (Richter *et al.* 2013), meaning it was inhabited in the transition between the end of the colder/drier episode of the Last Glacial Maximum (*c*. 23,000 cal. BP), and the warming/wetting phase of the Bølling/Allerød (*c*. 15,000-13,000 cal. BP; e.g. Robinson *et al.* 2006). An oxygen isotope sequence from the Nahal Soreq Cave in Israel suggests that the region underwent warming and wetting cycles leading up to the Bølling/Allerød, prior to the cooler and drier conditions of the Younger Dryas (Bar-Matthews *et al.* 1999; Rosen 2007). However, these broader, regional-scale climatic inferences are largely drawn from proxy records of the western Levant, e.g. Soreq cave or Dead Sea levels (Bar-Matthews *et al.* 1999) and may not capture past climatic conditions, or dynamics at Kharaneh IV, highlighting the need for site-specific environmental reconstructions (e.g. Jones *et al.* 2016).

In the environmental background (Chapter 3), I discussed that the site of Kharaneh IV does not currently look anything like it did historically, or, in all likelihood, in its recent past (also see Fariz and Hatough-Bouran 1998). When visiting the site today, even the untrained observer can conclude that the site now sits in a desert, with minimal vegetation and wildlife activity, restricted by the infrequency of rains and the lack of accessible groundwater (Fariz and Hatough-Bouran 1998; Jones *et al.* 2015). Hints of torrential rain downpours and intense past water events are evidenced by the veins of wide and sometimes deep wadis that cut through the landscape (personal observations). While it likely bore little resemblance to today's desert, the environmental conditions at Kharaneh IV 20,000 years ago remain somewhat

unknown. We also do not know whether the intensive span of occupation (1,225 years) at Kharaneh IV was linked to the ability of the site's human, plant and animal communities to access sufficient water resources.

We understand that proximity to water was essential for hunter-gatherer groups, specifically the access to multiple subsistence opportunities that these locales provided (Tsatskin and Nadel, 2003). Additionally, Mithen (2011), in discussing the domestication of water, has made the somewhat obvious point that where there are concentrations of human artefacts, there was water (but see Messerili *et al.* 2000; Hamlin 2000). Both of these examples suggest, in accordance with Jones's (2013) discussion, that examining local palaeoenvironmental evidence alongside archaeological data will allow us to expand our knowledge of the relationships between water availability, environmental change and subsistence, along with the settlement and occupation patterns of hunter-gatherers at Kharaneh IV and, potentially, in the wider Azraq Basin.

In this section, I present my analysis of stable carbon isotopes from archaeobotanical remains to examine changing water stress during Kharaneh IV's occupation. My use of this novel application of stable carbon isotope research has provided us an additional proxy for water stress, delivering local, site-specific data, that has lessened the need to rely solely on regional climate reconstructions to understand past environmental change at Kharaneh IV. More broadly, we currently have very little climate data available for the period leading up to the Younger Dryas' and its impact on local environments in the Azraq Basin, so these new data can play a key role in increasing our understanding of the external environmental influences that groups or individuals may have had to dealt with at a local scale.

Stable carbon isotope analysis can potentially reveal more detail about changes in water availability than traditional archaeobotanical methods. The archaeobotanical results presented here (see Chapters 6) used the generalised ecology of the identified species found at Kharaneh IV as a proxy for water availability (see related work by Charles and Hoppe 2003; Charles *et al.* 2003; and Jones *et al.* 1995 on the ecology of weed species in agricultural settings). Because species differ in their water requirements, large changes in water availability will induce species turnover in the

community, e.g. wet-adapted species will be replaced by drought-adapted flora (Jackson and Overpeck 2000), which should be reflected in the charred seed assemblages recovered during excavation. However, smaller changes in water availability may not cause species turnover, especially if the species present have broad hydrological tolerances (Jackson and Overpeck 2000). Thus, by just examining species presence and absence we could miss small changes in water availability that may have affected the abundance and quality of food resources. In addition to this, due to preservation issues, we are limited by our ability to classify items to the species level which in turn limits our understanding of the exact ecological requirements of the assemblage and we must consider the reality that other taphonomic and cultural filters could impose biases on the presence of seeds that may have favoured or tolerated certain conditions.

9.2. Background: wet beginnings and dry endings?

Inferring water stress from archaeological crop remains using stable carbon isotope analysis has become an increasingly accepted methodology (e.g. Araus and Buxo 1993; Araus *et al.* 1997a; Araus *et al.* 1997b; Araus *et al.* 2007; Ferrio *et al.* 2005; Fiorentino *et al.* 2008; Fiorentino *et al.* 2015; Flohr *et al.* 2011; Heaton *et al.* 2009; Riehl 2008; Riehl *et al.* 2008; Stokes *et al.* 2011; Voltas *et al.* 2008). Though these methods have thus far only been applied to a restricted range of crop species, their potential to be applied more widely is great (Fiorentino *et al*. 2015). Here, I combine the analysis of charred seeds from wild species present throughout Kharaneh IV's occupation to test the hypothesis that steady access to water and water-reliant resources at or near Kharaneh IV may have disappeared around the time of its abandonment (Jones and Richter 2011; Richter *et al.* 2013).

Several lines of evidence suggest substantial water availability during Kharaneh IV's early occupation. Archaeologically sterile sediments directly underlying the occupation horizons at Kharaneh IV consist of clays and silts that include freshwater snails, indicating local standing water just prior to site occupation (Richter *et al*. 2013). Sediment mapping and absolute dating suggest that up to 23 ka BP there was a positive hydro-climatic balance at Kharaneh IV (Jones *et al.* 2015). Jones *et al.* (2015) also identified a section of the wadi near Kharaneh IV where water appears to have pooled. This Pleistocene wetland was likely fed by flowing surface water (Jones *et al.*

2015), rather than groundwater spring activity, as the main Azraq aquifers sit at least 100 m below Kharaneh IV (Al-Kharabsheh, 2000).

Although Kharaneh IV may already have been drying by the time of site occupation (Jones *et al.* 2015), substantial water was likely still available locally in the nearby wadi. Sedimentary sequences indicate open water, probably shallow, wetland deposits that overlap stratigraphically with the early occupation horizons in Kharaneh IV's nearby wadi (Jones *et al.* 2015). The wadi would likely have provided persistent water, at least during the early years of occupation (Jones *et al.* 2015). Further afield, water would have been continuously available in the Azraq Oasis, which was within a two day foraging range from Kharaneh IV (Garrard and Byrd 2016). Furthermore, zooarchaeological evidence has demonstrated that Kharaneh IV was utilised by large numbers of gazelle and waterfowl, suggesting easy local access to standing water (Martin *et al*. 2010; Jones 2011). Lastly, archaeobotanical evidence from the neighbouring coeval site of Wadi Jilat 6 suggests a moist steppic environment with pools of water (Colledge 2001); unfortunately there is no further information on variation in water availability throughout occupation at Wadi Jilat 6.

These wetter conditions may not have lasted throughout Kharaneh IV's occupation. Although we lack direct evidence, several lines of indirect evidence point to this possibility. Jones *et al.* (2015) noted that a substantial drying out of the local environment is reflected in the existence of a silty loam with carbonate concretions, which was described by Besancon *et al.* (1989) and Garrard *et al.* (1985); unfortunately these are now largely missing due to deflation of the site. Based on a palaeo-groundwater study of Jordan, Bajjali and Abu Jaber (2001) also suggested a lack of significant groundwater recharge in the Azraq Basin after 18,000 cal. BP and Jones and Richter (2011) found sedimentary evidence of a reduction of water levels elsewhere in the Azraq Oasis during this time period. Thus, based on available evidence, a hypothesis for Kharaneh IV's decline and eventual abandonment is increasing water scarcity, potentially linked to increased evaporation as climatic conditions began to warm at the end of the Pleistocene (Richter 2007).

In contrast to the above, at a regional and global scale, the occupation of Kharaneh IV seems to sit within a period of increased precipitation (Bar-Matthews *et al.* 1997;

Jones *et al.* 2007), though the climate dynamics during the Late-Glacial-Interglacial transition in the region are still not fully understood (Robinson *et al.* 2006; Enzel *et al.* 2008). These discrepancies raise the possibility that broader-scale climate data may fail to represent local environmental conditions and their impacts on confined human settlements at a specific location, highlighting the need for site-specific environmental data for Kharaneh IV.

9.3. Theoretical basis of using stable carbon isotopes in archaeobotany and plant physiology

Here I outline the theoretical background of how the analysis of stable carbon isotopes can help address the paucity of local environmental information for Kharaneh IV. I also present the relevant background needed in plant physiology to plan, perform and interpret my analysis.

Stable carbon isotopes $\delta^{13}C$

Carbon has two stable isotopes (atoms of the same element with different masses): ^{12}C and ^{13}C (Hoefs 1997). The ratio of ^{13}C to ^{12}C is expressed in parts per mille (‰) relative to a standard due to the relatively low amount of ^{13}C in comparison to ^{12}C usually using delta notation, i.e. $\delta\,^{13}C$. Unlike ^{14}C which decays over time (used for dating), ^{13}C and ^{12}C isotopes are stable and their ratio, theoretically, does not change from when an organism dies to when it is studied; even after thousands of years it can give us a good prediction of the conditions (Boutton 1991a; Dawson and Brooks 2001; Hoefs 1997).

Plants acquire their carbon content as CO_2 from the air and preferentially take up the lighter isotope ^{12}C while discriminating against the heavier ^{13}C (Farquhar *et al.* 1982; O'Leary 1981). This results in $\delta^{13}C$ ratios that are lower (more negative) than those in the air. This discrimination is represented by $\Delta^{13}C$, which denotes plants' carbon isotope ratio relative to the ratio in the air (Ehleringer 1991; O'Leary 1981):

$$\Delta^{13}C = \frac{\delta^{13}C_{air} - \delta^{13}C_{plant}}{1 + \delta^{13}C_{air} \div 1000}$$

In addition to changes in $\delta^{13}C_{air}$, which is influenced by atmospheric CO_2 levels, numerous factors can influence $\Delta^{13}C$, including the plant photosynthetic pathway, water stress, and a number of other environmental factors.

9.4. Factors influencing $\Delta^{13}C$ in plants

Photosynthetic pathways: C_3 and C_4 plants

The magnitude of discrimination against ^{13}C depends on a plant's photosynthetic pathway, which fall into three groups: C_3, C_4, and CAM (the latter is not discussed here). The main photosynthetic pathways are C_3 and C_4 (Salisbury and Ross 1992). These pathways are named after the number of carbon atoms present in the first molecular product after carbon fixation occurs (Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991).

C_4 plants tend to originate in subtropical areas and are adapted to warm or semi-arid environments. They absorb carbon 13 (^{13}C) at a quicker rate than carbon 12 (^{12}C) so $\delta^{13}C$ is in the range of -16 to -10‰ (O'Leary 1988; Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). Typical examples of C_4 plants are: millet, sorghum, maize, fonio and papyrus (Sealy 2001; Boutton 1991b; Hubick *et al.* 1990).

C_3 plants are typically found in temperate climates and are called C_3 because they convert carbon to a compound containing three carbon atoms (Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). They exist in a broader range of environments than C_4 plants (Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). C_3 plants discriminate more against ^{13}C than C_4 plants, which results in lower $\delta^{13}C$ ratios and larger differences between plant tissues and atmospheric CO_2 (higher $\Delta^{13}C$) (Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). For C_3 plants, $\delta^{13}C$ is typically -33 to -24‰ (O'Leary 1988; Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). Examples of these plants include almost all trees, rye, barley, potatoes, spinach, rice, wheat, and many common fruits and vegetables (Boutton 1991; Sealy, 2001).

Water stress

Water availability directly affects ^{13}C discrimination (Farquhar *et al.* 1982, 1989; Farquhar 1983; Ehleringer 1991). Water availability is determined by several potential channels of input, including rainfall, anthropogenic watering and groundwater. It also depends on soil type, and rates of evaporation and evapotranspiration, which are affected by humidity, temperature, and wind speed (Batanouny 2001).

Water availability affects ^{13}C discrimination during photosynthesis through the opening and closing of plants' stomata. When open, the stomata permit the outflow of water (allowing the plant to cool and the movement of nutrients), ensuring the free absorption of CO_2 and maximum discrimination against C^{13}, resulting in higher ΔC^{13} values. When the stomata are closed, as in drought conditions, water is conserved within the plant and the availability of CO_2 is restricted, resulting in minimum ^{13}C discrimination and lower ΔC^{13} values. Therefore, ΔC^{13} serves as a proxy for water availability via the latter's effect on stomatal conductance (Ehleringer *et al.* 1993, Farquhar *et al.* 1989; Farquhar *et al*. 1982; Farquhar and Richards 1984; Stewart *et al*. 1995).

Other environmental factors

In addition to water availability, a range of other environmental factors can also influence $\Delta^{13}C$. These include soil fertility and nutrient availability (Batanouny 2001. Condon *et al*. 1992; Heaton 1999; Tieszen 1991), salinity, where in studies on wheat Shaheen and Hood-Nowotny (2005) found that high soil salinity produced a linear and significant ($P < 0.001$) decrease in $\Delta^{13}C$ (see also Yousefi *et al.* 2009), and temperature (Heaton 1999; Hillaire-Marcel 1986; Tieszen 1991; Troughton and Card 1975) and light intensity (Broadmeadow and Griffiths 1993; Heaton 1999; Hidy *et al.* 2009; Smith *et al.* 1976), through their effect on evaporation rates. Increased evaporation rates can cause plants to close stomata to conserve water (Ferrio *et al.* 2006; Farquhar *et al*. 1989), and thus are also linked to water stress, since water conservation is more important in water-limited areas. In addition, soil salinity can modify plant $\Delta^{13}C$ (Yousefi *et al.* 2009), which could obscure influences of water availability, or lead to incorrect inferences if changes in $\Delta^{13}C$ are attributed to changes in water availability, rather than salinity, or nutrient availability. Despite all of these potential influences on $\delta^{13}C$, in relatively dry regions like Eastern Jordan where water is the foremost limiting factor on photosynthesis, water availability is the principal determinant of stomatal activity during episodes of carbon fixation, and therefore, the primary determinant of $\Delta^{13}C$ in the Mediterranean (Hartman and Danin, 2010).

Species differences

The extent of discrimination against C^{13} varies between plant species, so $\Delta^{13}C$ from one species will differ from another, even if equivalent amounts of water are

available. $\Delta^{13}C$ can also vary between genotypes within species, particularly between landraces (Araus *et al.* 2007; Condon *et al.* 1990). It has also been shown that different plant parts have different $\Delta^{13}C$ values due to their different biochemical compositions, with more composite compounds having higher $\Delta^{13}C$ values (Condon *et al.* 1992; Hillaire-Marcel 1986). Grains, which contain mainly starch, also have a lower $\Delta^{13}C$ than other plant parts (Araus *et al.* 1992; Merah *et al*. 2002) which is why it is essential to use the same part of the same species of plant when analysing $\Delta^{13}C$. The primary message to take away from this theoretical background of carbon isotopes in plants is that ΔC^{13} can serve as a proxy for water availability due to this factor being one of the primary determinants of stomatal conductance (Ehleringer *et al*. 1993, Farquhar *et al*. 1989; Farquhar *et al*. 1982; Farquhar and Richards 1984; Stewart *et al.* 1995).

9.5. Stable isotope use in archaeobotanical analyses

In 1985, DeNiro and Hastorf, shortly followed by Marino and DeNiro (1987), proposed that since stable isotopes from archaeobotanical remains echo the environmental conditions that they grew in, they could provide reference values for archaeological food studies. Also in the 1980s, Farquhar and Richards (1984) and Condon *et al.* (1987) began to examine the relationship between water status and $\delta^{13}C$ in cereal crops. Building on this, in 1993, Araus and Buxó published an innovative study using stable carbon isotopes to track $\Delta^{13}C$ in cultivated cereals uncovered from multiple archaeological sites in Catalonia (N.E Spain). In addition to trying to account for changes in CO_2 over time, Araus and Buxó (1993) discussed an observed change in $\Delta^{13}C$ that they proposed could represent a change in aridity.

In 1997, Araus *et al.* (1997a, 1997b) published two more papers that took this technique further and used the method to indicate irrigation practices by comparing the carbon isotope discrimination ratios of archaeological grains to modern examples grown under controlled conditions. Their results indicated that differences in either environmental factors or water management practices could be identified from carbon isotope analysis of archaeobotanical remains. Ferrio *et al*. (2005) added to this discussion by demonstrating that if other climate indicators, or the carbon isotope ratios of wild plant species from the same site, indicate there was higher water

availability based on analysis of crop species than expected, artificial irrigation may have been used.

This method has since been employed on many archaeological sites to suggest higher water status for crops than would be expected from the rainfall in the region (see: Fiorentino *et al.* 2008; Riehl *et al.* 2008a, 2009; Riehl 2008; Ferrio *et al.* 2005, 2006a; Aguilera *et al.* 2008; Auraus *et al.* 1997a, 1999, 2007; Araus and Buxó 1993; Roberts et al. 2010, Bogaard *et al.* 2013; Vaiglova *et al*. 2014; Wallace *et al.* 2013).

In contrast, Ferrio *et al.* (2005) compared the isotopic values of wild weeds to crops from an archaeological site in north-east Spain and found relatively similar values, indicating that no irrigation had taken place. These results indicate that carbon isotope analysis of archaeobotanical remains can provide useful information on water availability and climatic change at very local, site-specific, scales. Here, it should also be noted that all of the above mentioned isotopic research has been done on material originating from archaeological sites occupied well after the emergence of agriculture.

9.6. Hypothesis

Here, I hypothesise that reduced water availability contributed to the abandonment of Kharaneh IV around 18,600 cal. BP. Given that in the Near East, water availability is the primary factor controlling carbon isotope variability in plants (Hartman and Danin 2010), I predict that, within a species, charred seeds recovered from shallower, younger, stratigraphic layers will have lower $\Delta^{13}C$ values than those from deeper, older layers. In doing so, I respond to Fiorentino's (2015) call to expand carbon isotope analysis in archaeobotany beyond crops by analysing pre-agricultural wild species. This work will also provide valuable additional data on the palaeo-environment at Kharaneh IV, and the Azraq Basin as a whole, supplementing regional models with additional site-specific data.

Chapter 10. Methods, Methodological Considerations and Stable Carbon Isotope Results

Isotope Methods and Methodological Considerations

10.1. Sample and species selection

For the purposes of this study 33 samples were selected, originating from 14 unique stratigraphic layers (loci) spanning the duration of occupation, from both areas A and B of Kharaneh IV. Again, as noted in Chapter 4, in order to make the best of the patchy information available on the matrix/chronological order of the samples I had access to, I created these stratigraphic zones, or groupings in order to put the samples into chronologically secure and dated groupings to allow us to securely observe change over time.

The samples were recovered during the 2008-2010 field seasons and were washed, prepared, sorted and identified using the methods fully detailed in Chapter 5. Three taxa, *Nitraria schoberi*, *Atriplex* sp., and cf. Compositae Kernels were selected from the Area A and Area B archaeobotanical samples based on relative abundance throughout the sequence of Loci at Kharaneh IV.

The identification of these small and poorly preserved seeds also added a challenge. As discussed by Wallace *et al.* (2013), we can only compare like species with like, so the main objective was to be sure that the species studied were the same. The majority of the non-wood-charcoal plant material recovered from the samples studied in this PhD was too small, too poorly preserved, or not present throughout the whole sequence of stratigraphic layers to be used in this isotope study.

The *Nitraria schoberi* seeds are by far the most securely identified species in the samples. Their distinct large size and morphological features made identifications easy (see Appendix 3: Seed Catalogue for full description and criteria of taxa).

My inability to identify the *Atriplex* sp. any further than the genus was due to the general state of preservation of the seeds. They appear to be slightly “puffed”, which

is likely due to heat (from fire) that distorts their general appearance. However, based on shape, size, surface patterns and consistency and after comparisons with two reference collections, I am confident that all of the seeds fitting this *Atriplex* sp. description are one species, however, in the interest of certainty I still decided to only take the identification as far as the genus level. (see Chapter 5 for identification methodology and Appendix 3 for full species description).

The cf. Compositae kernels were initially selected from Kharaneh IV's Area A and Area B archaeobotanical samples based on relative abundance throughout the sequence of Loci and a somewhat uniform shape and size although, the insecurity over their identification has caused me to proceed with caution (see Appendix 3 for full description of the samples classified as cf. Compositae kernels). Despite these reservations, I had the luxury of running a few additional samples so I ran them for experimental purposes. Had they all been the same species we should expect to see some similarities in the results (as in the $\delta^{13}C$ should be relatively similar amongst all the samples run).

The preparation and analysis of all isotope samples was undertaken at the NERC Isotope Geosciences Facilities laboratories in Keyworth, Nottinghamshire, United Kingdom in the autumn of 2015. The funding for this project was awarded from the NERC Isotope Geosciences Facilities Steering Committee, Project: (IP-1525-0515), and covered the analysis of the samples

10.2. Methodological considerations

Carbonisation and stable isotope composition

Experimental studies examining the variation in $\delta^{13}C$ from charring have concluded that for carbon isotopes, charred archaeobotanical remains preserve their original isotopic composition. (see DeNiro and Hastorf 1985; Hastorf and DeNiro 1985; Marino and DeNiro 1987; Araus *et al.* 1997b; Ferrio *et al.* 2007; Yang *et al.,* 2011; Fraser *et al.,* 2013).

Soil contaminants and post depositional alteration considerations

Much of the archaeobotanical material removed from archaeological soils generally has substances encrusted on them, which may alter their isotopic composition, though

this depends heavily on soil conditions (DeNiro and Hastorf 1985). Carbonate precipitates/crusts and humic/fluvic acids tend to be the most common forms of contaminants. Many studies have followed the DeNiro and Hastorf's (1985) standard protocol, which advocates soaking samples with HCI, rinsing, then soaking in NaOH, rinsing again and then soaking again in HCI. However, recent studies by Fraser *et al.* (2013) and Strying *et al.* (2013) both concluded that the use of a less intensive acid-base-acid pre-treatment was sufficient. Vaiglova *et al.* (2014) concluded that most contaminants could be removed using a gentle acid-only treatment (for carbonates), that thorough rinsing removes nitrates, and a gentle acid-based treatment can be used for the removal of humic/fluvic acids. Vaiglova *et al.* (2014) also recommended the use of Fourier transform infrared spectroscopy (FTIR) to detect contamination. They (*ibid*), however, argued that it is not necessary to try to remove humic acid contamination for stable isotope analysis. At the most recent International Working Group of Palaeoethnobotany conference in Paris, July 2016, Otto Brinkkemper also noted that his on-going research suggests that there is no need for pre-treatment if the risk of losing material is high. I agree with all of the above mentioned suggestions for pre-treatment when potential samples are numerous and the seeds themselves are large. Here, however, I decided to forgo all pre-treatment because, after communications with Petra Vaiglova (Oxford) and Angela Lamb (NERC Geosciences, BGS), there was a lack of visible contamination on the seeds, the risks of losing too much material during the pre treatment process was high, and there were limited site samples. Realistically the options were to run the samples as they were, or risk not having any samples to test whatsoever. In the interest of gleaning the most information possible, I went with the latter.

Chronological considerations

The samples presented here originate from the full range of stratigraphic layers (Loci) present at Kharaneh IV. In 2013, Richter *et al.* published a series of radiocarbon dates for the duration of occupation at Kharaneh that correspond well (they are from above, below and within) the series of samples that I have tested here (see Figure 5.3 for a schematic diagram of the dated Loci and the stratigraphic order of my samples). Richter *et al.* (2013) used a Bayesian OxCal site phase model to conclude that the occupation of Area A spanned from 18,600 cal. BP to 18,850 cal. BP, and from 18,730 cal. BP to 19,830 cal. BP in Area B, indicating the site's occupation spanned a

maximum of 1,225 years. This model also placed the occupation of Area A approximately on top of that of Area B, suggesting that during the earlier phases, Area B was used, and was followed by a transition to the use of Area A. However, due to deflation and missing and disturbed surface layers in Area B, it is unclear when the occupation of Area B ended (Richter *et al.* 2013). Richter *et al.* (2013) suggested that despite the separation of Areas A and B, the stratigraphic relationship and phasing of the site can be considered a continuous depositional sequence.

For the purpose of my study, it is important that we understand the stratigraphic order and the location (Loci) of the samples. Thus, I have placed the samples in stratigraphic order, relying on the principle that as we go deeper, in undisturbed stratigraphic layers, we are in fact going back in time. Therefore, by analysing the carbon isotopic composition of samples from the surface, mid layers and the very bottom of the site, I can test for changes in water availability throughout all of Kharaneh IV's phases of occupation at Kharaneh IV.

10.3. Sample preparation

The individual *Nitraria schoberi* samples were carefully crushed and homogenised using a marble mortar and pestle in a clean and controlled environment. The homogenised product was then weighed and, if sufficient material was available, split into two and placed into small tin capsules. I aimed for a minimum of 0.03 mg in each capsule, however, in cases where I had less than 0.03 mg available I prepared the sample as above.

The *Atriplex* sp. seeds were not homogenised due to their small size and the limited number of samples available, as I feared that most of the material might be lost during crushing. Each *Atriplex* sp. sample consisted of 3-4 seeds originating from the same locus and trench square. Each sample was weighed and combined in one tin capsule. The cf. Compositae kernel samples were carefully crushed and homogenised using a marble mortar and pestle in a clean and controlled environment. The homogenised product was then weighed and, if sufficient material was available, split into two and placed into small tin capsules. I aimed for a minimum of 0.03 mg in each capsule.

10.4. Mass spectrometry methods

Costech/Triple Trap/Mass spectrometer $^{13}C/^{12}C$ and C/N method

$^{13}C/^{12}C$ analyses were performed by combustion in a Costech Elemental Analyser (EA) on-line to a VG TripleTrap and Optima duel-inlet mass spectrometer with $\delta^{13}C$ values calculated to the VPDB scale using a within-run laboratory standards calibrated against NBS18, NBS-19 and NBS-22. Replicate analysis of well-mixed samples indicated a precision of ±<0.1‰ (SD). C/N ratios were also measured and were calibrated against an Acetanilide standard. Replicate analysis of well-mixed samples indicated a precision of ±<0.1‰.

$^{13}C/^{12}C$ ratios and %C and N of bulk organic matter were analysed in an online system comprising a Costech ECS4010, a Costech chromatography software package (EAS 1.7), a VG TripleTrap and VG optima mass spectrometer. My samples that contained 1 to 2 mg C, were loaded into tin capsules and placed in the carousel of the EA. The samples were then sequentially dropped into a continuous flow of helium carrier gas, into a 1,020°C furnace. Then a pulse of oxygen gas promoted an exothermal flash oxidation of the tin capsule, ensuring full combustion of the sample and the product gases were further oxidised by chromium and cobaltous oxide in the lower part of the furnace. After the removal of excess oxygen and water (by passage through hot copper and magnesium perchlorate), the remaining N_2 and CO_2 then pass through a GC column and by a thermal conductivity detector. This generated an electrical signal proportional to the concentrations of N_2 and CO_2 and present in the helium stream.

The Costech EAS software station acquires and evaluates this information, producing %N and %C data for the sample. Then, using a standard sample of known composition under the same operating conditions, it was possible to calibrate the instrument and quantify the contents of nitrogen and carbon of the unknown samples. To achieve this, I have included a series of known standards mixed throughout my unknown samples.

Meanwhile, the helium stream was carried out the N_2 and CO_2 through a trap at -90°C (for complete removal of the water), before reaching the Triple Trap held at -196°C. Here the CO_2 is frozen, allowing the N_2 and helium to vent to atmosphere. The

TripleTrap is then evacuated before warming the CO_2 trap and expanding the sample CO_2 into the inlet of the Optima.

The Optima mass spectrometer has triple collectors allowing simultaneous monitoring of CO_2 ion beams at m/e=44, 45 and 46; and dual inlet allowing for the rapid comparison of sample CO_2 compared with a reference of CO_2. 45/44 ratios are converted to $^{13}C/^{12}C$ ratios after correction for common ion effects (known as the 'Craig' correction).

This system preforms an automated run on up to 50 samples at a time; however, I ran my samples in two batches in two separate runs. In each run I placed approximately 10 replicates of the laboratory standard (BROC2). From knowledge of the laboratory standards $\delta^{13}C$ value *versus* VPDB (derived from regular comparison with internal calibration and reference material NBS-18, NBS-19 and NBS-22), the $^{13}C/^{12}C$ ratios of the unknown samples were converted to $\delta^{13}C$ values *versus* VPDB.

10.5. Calculating $\Delta^{13}C$

$\Delta^{13}C$ depends on $\delta^{13}C$ of the plant and of the air (Eq. 1). Thus, changes in atmospheric CO_2 can alter $\Delta^{13}C$ through time, and therefore, when comparing $\delta^{13}C$ for plants through time, we need to account for possible changes in the $\delta^{13}C$ in the air.
Ice cores from the Antarctic provide an extensive record of global atmospheric changes in $\delta^{13}C_{air}$. In Fiorentino *et al.*'s (2015) overview of the archaeological research using stable isotopes they considered ice-core data as the most suitable reference value for $\delta^{13}C_{air}$ in archaeological material. Their analysis used Ferrio *et al.*'s (2005, 2006) curve of $\delta^{13}C_{air}$ through most of the Holocene, which used interpolated data from Antarctic ice cores with modern data from Antarctic stations of the CU-INSTAAR/NOAA-CMDL network for atmospheric CO_2 (ftp://aftp.cmdl.noaa.gov/ccg/co2c13/flask/readme/html). However, this dataset does not extend early enough for Khareneh IV. Instead, I obtained $\delta^{13}C_{air}$ values from an ice core taken by the European Project for Ice Coring in Antarctica (EPICA) Dome C dataset (Lourantou *et al*. 2010), which provided climate data well into Kharaneh IV's occupation period (up to 26 K BP). The EPICA Dome C ice core was analysed to compare the evolution of CO_2 and its stable carbon isotopic ratio ($\delta^{13}C$ CO_2).

As $\delta^{13}C_{air}$ may change through time, I repeated my analysis using two different measures of $\delta^{13}C_{air}$ for each sample. In the first, I used the average $\delta^{13}C_{air}$ value across Kharaneh IV's occupation (mean $\delta^{13}C_{air}$ =-6.52) for all samples. For the second method, I interpolated $\delta^{13}C_{air}$ using a linear function to obtain the value at the midpoint of the dating range for each stratigraphic zone (Table 10.1). This latter approach accounted for the slight changes in $\delta^{13}C_{air}$ that occurred during Kharaneh IV's occupation. As can be seen in the Results (Chapter 12), these different measures gave the same results, showing my findings are robust to the small changes in $\delta^{13}C_{air}$ that occurred during Kharaneh IV's habitation.

Table 10.1. Interpolation of $\delta 13C_{air}$ values for each stratigraphic zone. $\delta 13C_{air}$ values were interpolated for each zone's midpoint date by interpolation using the $\delta 13C_{air}$ values for the closest dates from the EPICA Dome dataset (Lourantou *et al.* 2010) that fully span each Zone's date range.

Stratigraphic Zone	Earliest Likely Date (BCE)	Latest Likely Date (BCE)	Date Mid-point (BCE)	Early Epica Dome (BCE)	Late Epica Dome (BCE)	Early Epica Dome $\delta^{13}C_{air}$	Late Epica Dome $\delta^{13}C_{air}$	Interpolated $\delta^{13}C_{air}$
A1	18864	18546	18705	19904.48	18148.13	-6.600	-6.740	-6.696
A2	19220	18556	18888	19904.48	18148.13	-6.600	-6.740	-6.681
B1	19400	18696	19048	19904.48	18148.13	-6.600	-6.740	-6.668
B2	19793	18935	19364	19904.48	18148.13	-6.600	-6.740	-6.643
B3	19821	18930	19375.5	19904.48	18148.13	-6.600	-6.740	-6.642

10.6. Statistical analyses

$\Delta^{13}C$ values for *Nitraria schoberi*, *Atriplex* sp. and cf. Compositae kernel were compared separately using linear mixed effects models with stratigraphic zone as a fixed effect and loci as a random effect. This approach accounts for the non-independence of seed remains taken from within a locus as these do not represent fully independent information. The approach essentially compares the differences between stratigraphic zones with the variation in $\Delta^{13}C$ values within zones. I carried out these analyses using the nlme package (Pinheiro *et al.* 2016) in R v3.3.2 (R Core Team 2016).

Stable Carbon Isotopes Results

10.7. *Nitrari schoberi*

Figure 10.1 shows $\Delta^{13}C$ values for *Nitraria schoberi* across stratigraphic zones, using mean $\delta^{13}C_{air}$ values. $\Delta^{13}C$ is clearly highest in B2, with lower values in B3 and A1. These overall differences are statistically significant (F=39.01, df=2,3, P=0.007). Specifically, $\Delta^{13}C$ was significantly higher in B2 than in B3 (t=8.44, df=3, P=0.003) and A1 (t=5.25, df=3, P=0.013). However, B3 and A1 were not significantly different (t=2.18, df=3, P=0.12). These results are summarized in Table 10.2. Additionally, the values of $\delta^{13}C_{plant}$ ranging from -23.7 to -24.8 (Table 10.3) indicate that *Nitrari schoberi* is a C_3 plant, which was unknown prior to this analysis.

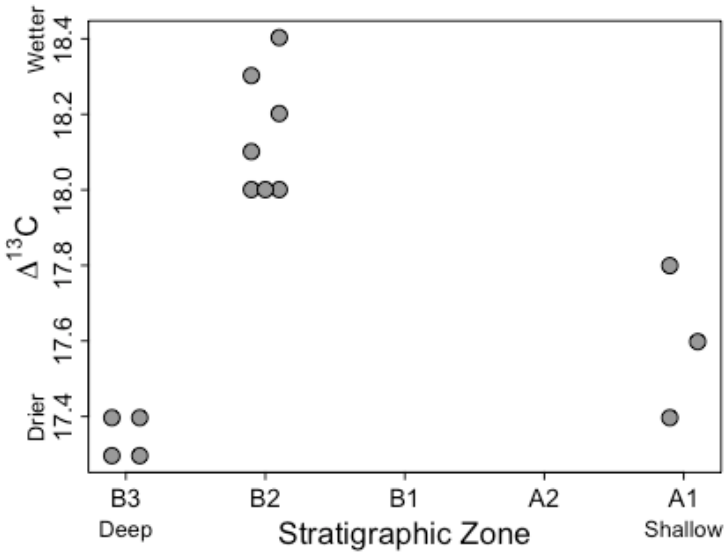


Figure 10.1. $\Delta^{13}C$ against stratigraphic zone for *Nitraria schoberi*. Values were randomly jittered on the X-axis to avoid overlap. $\Delta^{13}C$ values were calculated using the mean $\delta^{13}C_{air}$ values across the occupation period of Kharaneh IV.

Table 10.2. Mean (s.e.) $\Delta^{13}C$ and P-values of $\Delta^{13}C$ contrasts between stratigraphic zones for *Nitraria schoberi.* Mean (s.e.) values are on the diagonal. Off-diagonals give P-values of contrasts between zones (fixed effects). P-values < 0.05 are significant. Locus was included in models as a random effect.

	B3	B2	A1
B3	17.35 (0.08)		
B2	0.0035	18.14 (0.06)	
A1	0.12	0.014	17.60 (0.09)

Table 10.3. $\delta^{13}C_{plant}$ and $\Delta^{13}C$ levels for *Nitraria schoberi* (N), *Atriplex* sp. (A), and cf Compositae Kernel (C) seed samples from Kharaneh IV. $\delta^{13}C_{plant}$ values were obtained using mass spectrometry. $\Delta^{13}C$ values were calculated using the mean $\delta^{13}C_{air}$ (-6.5167) across the period of Kharaneh IV's occupation from the EPICA Dome dataset (Lourantou *et al.* 2010).

Isotope sample code	Locus	Species	d13C.plant	D13C	Stratigraphic Zone
ATX2	67	A	-10.9	4.412085423	2A
3MA	27	A	-10.9	4.412085423	2B
ATX1	76	A	-11	4.512741365	2A
6MA	31	A	-11.2	4.714053247	3B
2MB2	4	A	-11.3	4.814709188	2B
5MA	28	A	-11.4	4.915365129	2B
CK5	57	C	-25.3	18.90654096	1A
CK6	57	C	-26.2	19.81244443	1A
CK4	65	C	-25.3	18.90654096	1A
CK7	67	C	-25.5	19.10785284	2A
CK8	84	C	-26	19.61113255	2A
CK9	76	C	-26.2	19.81244443	2A
CK2	35	C	-26.7	20.31572414	1A
CK3	35	C	-25.3	18.90654096	1A
CK1	3	C	-26	19.61113255	1A
4CA	27	C	-25.6	19.20850878	2B
3CA	4	C	-26.9	20.51703602	2B
3CA2	4	C	-26.9	20.51703602	2B
3CB	4	C	-24.9	18.50391719	2B
3CB2	4	C	-24.9	18.50391719	2B
NT2	3	N	-24.2	17.79932561	1A
NT1	3	N	-23.8	17.39670184	1A
NT3	3	N	-24	17.59801372	1A
4NA	30	N	-23.8	17.39670184	3B
5NA2	31	N	-23.8	17.39670184	3B
5NA	31	N	-23.7	17.2960459	3B
4NA2	30	N	-23.7	17.2960459	3B
1NA	5	N	-24.4	18.00063749	2B
1NA2	5	N	-24.7	18.30260531	2B
2NA	4	N	-24.5	18.10129343	2B
2NA2	4	N	-24.6	18.20194937	2B
3NA	27	N	-24.4	18.00063749	2B
3NA2	27	N	-24.4	18.00063749	2B
3NB2	27	N	-24.8	18.40326125	2B

10.8. *Atriplex* sp.

Variation in $\Delta^{13}C$ using mean $\delta^{13}C_{air}$ for *Atriplex* sp. is shown in Figure 10.2. *Atriplex* sp. has a small sample size within each zone and thus there is little statistical power to detect differences. Given this small sample size, there were no significant differences between $\Delta^{13}C$ of *Atriplex* sp. in any of the stratigraphic zones where it was found ($F=0.86$, $df=2,3$, $P=0.51$). See Table 10.4 for details on pairwise comparisons between

zones, none of which were significant. Although there were no apparent differences in $\Delta^{13}C$ between zones, according to the values of $\delta^{13}C_{plant}$ ranging from –10.9 to -11.4 (Table 10.3) the *Atriplex* sp. seeds are from a C_4 plant which was not known prior to this analysis.

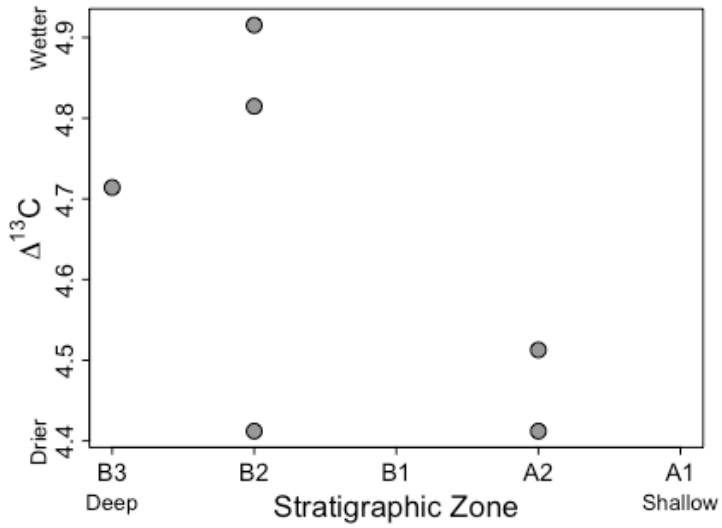


Figure 10.2. $\Delta^{13}C$ against stratigraphic zone for *Atriplex* sp. $\Delta^{13}C$ values were calculated using the mean $\delta^{13}C_{air}$ values across the occupation period of Kharaneh IV.

Table 10.4. Mean (s.e.) $\Delta^{13}C$ and P-values of $\Delta^{13}C$ contrasts between stratigraphic zones for *Atriplex* sp. Mean (s.e.) values are on the diagonal. Off-diagonals give P-values of contrasts between zones (fixed effects). P-values < 0.05 are significant. Locus was included in models as a random effect.

	B3	**B2**	**A2**
B3	19.45 (0.33)		
B2	1.0	4.71 (0.13)	
A2	0.42	0.30	4.46 (0.16)

10.9. cf. Compositae kernel

Results for $\Delta^{13}C$ using mean $\delta^{13}C_{air}$ for cf. kernel are shown in Figure 10.3. There is substantial variation in $\Delta^{13}C$ values between zones. As suggested by Figure 10.3, there were no significant differences in $\Delta^{13}C$ between cf. Compositae kernel seeds from different stratigraphic zones (F=0.018, df=2,6, P=0.98). Details of pairwise comparisons are shown in Table 10.5. Following these results, no further analysis of

these samples has been done, as I am not confident of their secure species identification and they appear to span the whole spectrum with little pattern.

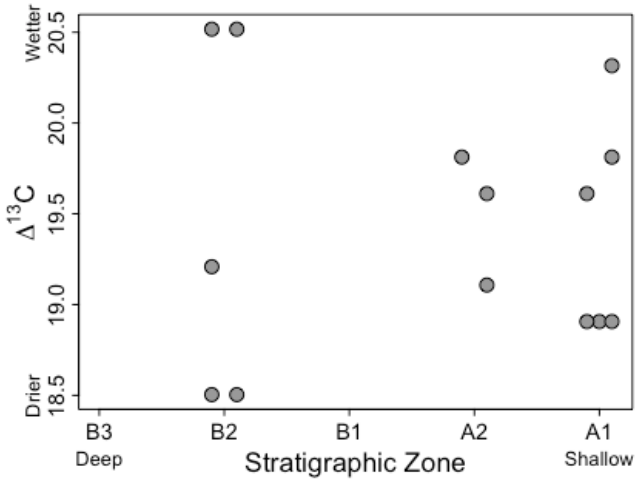


Figure 10.3. $\Delta^{13}C$ against stratigraphic zone for cf. Compositae Kernels. $\Delta^{13}C$ values were calculated using the mean $\delta^{13}C_{air}$ values across the occupation period of Kharaneh IV.

Table 10.5. Mean (s.e.) $\Delta^{13}C$ and P-values of $\Delta^{13}C$ contrasts between stratigraphic zones for cf. Compositae Kernels. Mean (s.e.) values are on the diagonal. Off-diagonals give P-values of contrasts between zones (fixed effects). P-values < 0.05 are significant. Locus was included in models as a random effect.

	B2	**A2**	**A1**
B2	19.45 (0.33)		
A2	0.92	19.51 (0.43)	
A1	0.93	0.86	19.41 (0.31)

10.10. Varying $\delta^{13}C_{air}$

Values of $\Delta^{13}C$ that allowed $\delta^{13}C_{air}$ to vary among stratigraphic zones were nearly identical to those using mean $\delta^{13}C_{air}$ for *Nitraria schoberi, Atriplex* sp., and cf. Compositae kernels (Figure 10.4). Statistical comparisons among zones were also nearly identical. These results demonstrate that that varying levels of atmospheric CO_2 during Kharaneh IV's occupation (Figure 10.5) did not confound my calculations and comparisons of $\Delta^{13}C$.

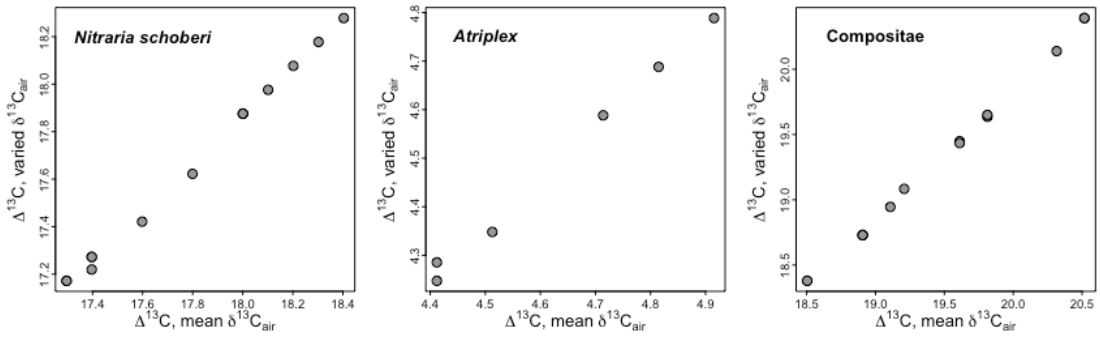


Figure 10.4. Relationships between $\Delta^{13}C$ calculated using the mean $\delta^{13}C_{air}$ across Khareneh IV's occupation and $\Delta^{13}C$ calculated using interpolated $\delta^{13}C_{air}$ values for the midpoint date of a stratigraphic zone. Both calculations used the Epica Dome dataset (Figure 10.5; Lourantou *et al*. 2010).

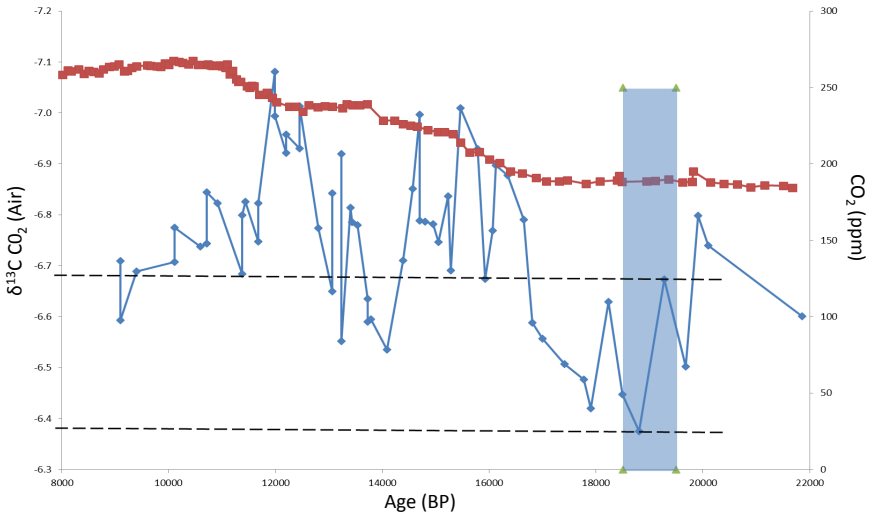


Figure 10.5. Variation in $\delta^{13}C_{air}$ from the Dome dataset (Laurantou *et al.* 2010).The left Y-axis and blue line and diamonds show corrected $\delta^{13}C$ CO_2 and the right Y-axis and red line and squares show CO_2 concentrations (ppm). The period of occupation at Kharaneh IV is delineated by the blue polygon and green triangles.

Chapter 11. Discussion, Conclusions and Challenges of Tracking Water Stress at Kharaneh IV

Here I consider the stratigraphic, chronological and environmental implications arising from the stable isotope analyses. Despite my limited sample size, variation in the $\Delta^{13}C$ values among the charred seeds from shallower, younger, stratigraphic layers and those from deeper, older layers suggests a history of changing water stress during occupation at Kharaneh IV.

11.1. *Nitraria schoberi*

The results from *Nitraria schoberi* were the most robust as I had access to the most samples for this species and was able to run 15 individual samples from 6 unique loci (see Table 10.3). The results were also consistent with the initial hypothesis suggesting that there were changes in water availability throughout occupation (see Figure 10.1). Comparing Figure 10.1 with the section drawing (Figure 11.1), three distinct groupings (both stratigraphically and isotopically) within the *Nitraria schoberi* samples can be distinguished.

Beginning at the very bottom of Kharaneh IV's stratigraphy, in stratigraphic zone B3, at the earliest levels of occupation, we tested two loci: 30 and 31, both associated with the beginning of the Early Kebaran cultural phase (Maher *et al.* 2012) and radiocarbon dated to 19,555-18,930 and 19,821- 18,989 cal. BP (Richter *et al.* 2013), respectively. These deep loci group together in the far bottom left of the figure and have $\Delta^{13}C$ ranging from 17.29–17.39‰ indicating relatively high water stress at the beginning of occupation. This relatively high water stress is difficult to explain, but as it represents the earliest stages of occupation at Kharaneh IV three explanations may be put forward. Explanation one is that despite the water stress experienced by the plants tested, the hunter-gatherers may have been fewer in numbers and thus required less water for the resources they utilised. The second is that they used the site for less water dependant/consuming activities. The third option is that, during this early period of occupation, the users were still fully nomadic and only occupied the site during seasonally wetter periods.

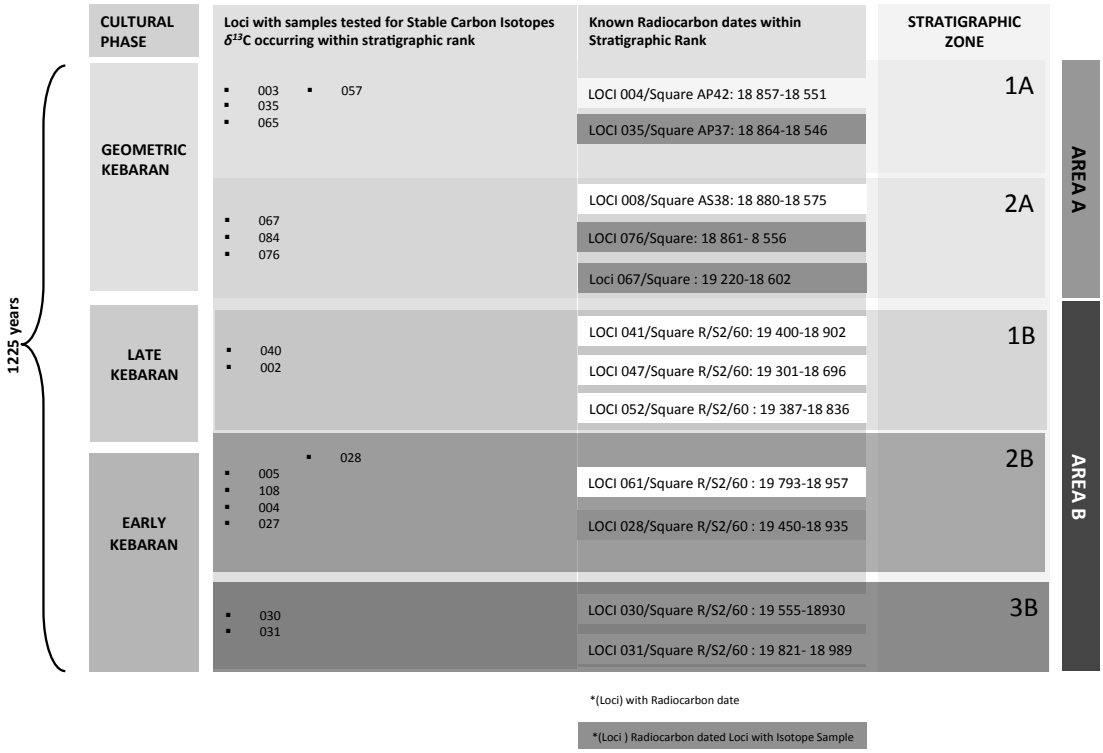


Figure 11.1. Location of Kharaneh IV isotope samples within their stratigraphic zones and associated radiocarbon dates calibrated age (BP) INTCal09.

As we move higher into Area B to stratigraphic zone B2—the mid occupation of Kharaneh IV, known as the Early Kebaran cultural phase (Maher *et al.* 2012)—there are samples from three loci: 27, 04 and 05 which cluster together. Their $\Delta^{13}C$ ranged from 18.00 to 18.40‰, suggesting that this period experienced relatively wetter conditions (lower stress) than the B3 locus samples from the deepest/oldest occupation layers of the site. In comparison with the stratigraphic sequence demonstrated in the section drawings (Figure 11.1), these loci sit just below the thick lens of locus 53 (roughly 20cm). This thick locus, which is relatively poor in archaeological remains, could indicate a period of limited or complete abandonment/disuse of the site of Kharaneh IV sometime shortly before 19,387-18,836 cal. BP (Richter *et al.* 2013) and before the beginning of the Late Kebaran cultural phase of the site. Considering that there are signs of relatively low water stressed plants just below Locus 53, and relatively higher water stressed plants just above, this may indicate that this locus could represent a period of abandonment due to water stress at Kharaneh IV, where the site became unfavourable to the hunter-gatherers.

The shallowest (near the surface) samples are from Stratigraphic Zone A1 and are all from the same locus: 3. Locus 3 is situated in the Geometric Kebaran cultural phase (Maher *et al.* 2012), which has been dated to after 18,857-18,551cal. BP (Richter *et al.* 2013). These samples sit alone in a cluster at the far right hand side of Figure 10.1, with their $\Delta^{13}C$ ranging from 17.40-17.80‰ suggesting a relatively drier period where these plants were forced to close stomata to reduce water loss, indicating relatively high water stress at the end of occupation. This period of high water stress at the end of occupation is consistent with a general drying of the environment, which could have resulted in fewer resources and abandonment of the site, as hypothesized by Jones and Richter (2011) and Richter *et al.* (2013).

What does *Nitraria schoberi*'s $\Delta^{13}C$ tell us?

Considering all of the *Nitraria schoberi* samples together, there are what appear to be fluctuating levels of water stress throughout the phases of occupation at Kharaneh IV, rather than a single unidirectional trend. Specifically, there is a relatively stressed beginning, followed by more favourable, wetter conditions during the prime of the site's occupation, followed by a return to a relatively harsher, more water-stressed environment in the final stages of occupation.

Adding a very local perspective to the broader regional climatic generalisations of Kharaneh IV, these *Nitraria schoberi* samples suggest that the relative water stress in the early occupation levels at Kharaneh could be reflective of the end of the cold/dry episodes of the Last Glacial Maximum (Robinson *et al.* 2006). This time of early water stress fits with the possibility that these early stratigraphic layers also represent less frequent, or shorter, visits to the site by the users of Kharaneh IV, as indicated by the low frequency of occupation floors and surfaces (see Simms 1988) during this period (see Figure 11.1).

The relative increase in water availability during the mid-occupation levels in Kharaneh IV's stratigraphic zone B2 may be evidence of one of the brief wetting cycles indicated by the oxygen isotope sequence from the Nahal Soreq Cave (Bar-Matthews *et al.* 1999). This may also reflect a time of increased site use, including longer stays or all-season use at the site and possibly a larger population size. All-season use has also been inferred from zooarchaeological analysis during this period

(Martin 2010, Jones 2011). Longer stays and/or high population size are also indicated by the high frequency of successive floors and occupational surfaces within this zone (see Figure 11.1), as is typical in Bedouin camps (Simms 1988).

11.2. *Atriplex* sp.

In general, the *Atriplex* sp. samples suggest a slight (but statistically insignificant) trend of a relative increase in water stress from the beginning to end of occupation at Kharaneh IV. These six *Atriplex sp.* samples originated from six unique loci that broadly span the length of occupation giving us a broad temporal perspective of this time period. Unfortunately, the very low sample size also means that the inferences that can be reliably drawn from these data are limited. Given the low statistical power, it is worth considering the patterns of *Atriplex* sp. Δ13C values, but with the caveat that whether they are indicative of real trends, or random variation, is unknown.

From the deepest (earliest), occupation levels associated with the lowest levels of the Early Kebaran cultural phase (stratigraphic zone B3), there is only a single Δ13C value of 4.71‰, from locus 31. This value, from the lowest, least intensely used levels of the site, does not indicate either particularly high or low water stress, relative to later levels, though little can be inferred from just a single value.

There are three samples in stratigraphic zone B2, which is still in the Early Kebaran phase Maher *et al.* 2012), but two of which (loci 4 and 27) are situated within the dense occupation floors (see Figure 2.3 and Figure 11.1). Both of these values show higher Δ13C values than the single value from B3, suggesting the possibility of similar, or lower water stress during this intensive period of occupation, which would be consistent with the findings for *Nitraria schoberi.* However, the third locus from zone B2, locus 28, shows a very different Δ13C value, which is much lower than the others from B2. In contrast to the suggestion above, this could indicate high water stress in zone B2, which contradicts the findings for *Nitraria schoberi*.

There are four possible explanations for this apparent contradiction. The first is that the sample size is too small to determine a reliable pattern. The second is that these seeds, while all from the genus *Atriplex,* are from different species whose seed remains are indistinguishable. Δ13C values should be compared among the same

species as interspecific differences can confound comparisons (Wallace 2013). A third possible explanation is that there is spatial heterogeneity in water availability in the area surrounding Kharaneh IV, consistent with Ramsy and Rosen's (2016) 'mosaic' landscape model, and the locus 28 sample came from a drier microhabitat. The fourth possibility is that there is fluctuating water stress during the time encompassed by zone B2. Within zone B2, locus 28 is the lowest (earliest) locus sampled here and it actually originates from underneath the more dense lenses of occupation that characterise B2 (Figure 11.1). High water stress at this earlier time would be closer to, but not perfectly in line with, the *Nitraria schoberi* results, which suggest that early high water stress was associated with reduced activity at the site. However, this would then partially contradict the lack of water stress indicated by the single B3 Δ13C value, again raising the problem of limited sampling and the prospect of finer scale water stress fluctuations or spatial heterogeneity in the surrounding habitat (see Ramsay and Rosen 2016, Ramsay *et al.* 2016.).

At the lower levels of Area A (but the highest available samples for *Atriplex* sp.), there are two samples from stratigraphic zone A2, loci 76 and 67. These loci have been associated with the Geometric Kebaran cultural phase (Maher *et al.* 2012). $\Delta^{13}C$ values from these loci are both low, indicating higher relative water stress during these final phases of occupation at Kharaneh IV, results that are consistent with those of *Nitraria schoberi* which also suggest a drying out of the surrounding environment toward the end of occupation.

It is more difficult to draw comparisons between the *Atriplex* sp. results and the larger, more generalised, climate trends. Variation in water stress for *Atriplex* is perhaps reflective of the warming/wetting cycles the Nahal Soreq Cave oxygen isotope sequence suggests for this time period (Bar-Matthews *et al.* 1999). Similarly to the *Nitraria schoberi* results, there is evidence that at least some of the samples tested here experienced relatively low water stress during the B2 stratigraphic zone and this can further be explained in knowing that the relatively dry sample here is from one of the lowest loci (28) within the B2 stratigraphic zone, and may indicate that conditions typical of the Last Glacial Maximum (Robinson *et al.* 2006) were still in effect here, with cold and dry remaining the norm. Also, with the relatively dry samples in stratigraphic zone A2, we may be seeing signs that the drying out of the site began in

as early as 18,861-18,556 cal BP, perhaps suggesting the site was being less used due to increasing water stress. Of course, it cannot be stressed enough that inferences from the *Atriplex* sp. are tentative speculation, given the small sample size.

11.3. The case of the curious cf. Compositae kernels

The cf. Compositae Kernel samples provided me with by far the least promising results. They showed an extremely wide range of $\Delta^{13}C$ values, from 18.50 to 20.52‰, which is double the variation seen in *Nitraria schoberi*. Moreover, despite a larger sample size than for *Atriplex* sp., there is no clear pattern or even the suggestion of a trend. This could arise because of the lack of fluctuations in water stress in the microhabitats inhabited by cf. Compositae. However, given the differences in water stress shown by *Nitraria schoberi* and suggested by *Atriplex* sp., this seems unlikely. Given that these kernels could only be identified tentatively to family, it is more likely that these kernels do not represent a single species, or even genus, which renders inferences of water stress from $\Delta^{13}C$ values inappropriate (Wallace *et al.* 2013). It is telling that the clearest trends in my analysis arose from those samples which could be identified unambiguously to a single species (*Nitraria schoberi*), with patterns of water stress declining as taxonomic resolution decreased to single genus (*Atriplex* sp.) and then to family (Compositae).

Our kernels were similar to those in the Abu Huyera reference collection, in which Gordon Hillman (2000) had identified a very similar "species" which he believed to be the inner core/kernel of a cf. Compositae Kernel. However, Hillman (2000) did not identify any diagnostic features other than overall shape and size for these kernels and neither could I. Thus it is possible, even likely, that they are from different species or even genera. An even more extreme possibility is that they are not even seed remains and that their uniform size and pinch marks on the ventral side could indicate they are faeces of a small mammal. Thus, although I have included these results here in order to fully report on the experimentation process and lessons I have learned, I do not feel confident that discussion or conclusions can be made from the isotope analysis of the cf. Compositae kernels.

11.4. Conclusions and challenges

Fiorentino *et al.*'s (2015) review of isotope research in archaeobotany specifically called for an expansion of stable isotope analysis to non-crop species and I have taken up the challenge of responding here with a new application of stable carbon isotope work on both rare and wild Epipalaeolithic material. Most of the previous work on stable carbon isotopes in archaeobotany has focused on inferring water status in crops (e.g. Araus and Buxo 1993; Ferrio *et al.* 2007; Fiorentino *et al.* 2012; Flohr *et al.* 2011; Riehl *et al.* 2008; Stokes *et al.* 2011). Here, I have expanded their application by applying a new methodology to a pre-agricultural site, where our information is very limited due to preservation issues. The analysis of wild seed samples from Kharaneh IV has demonstrated that it is possible to use stable carbon isotopes as a proxy for changing past water availability, but has also highlighted the challenges of this approach for hunter-gatherer sites.

The analysis demonstrated that Kharaneh IV likely experienced variable water stress throughout its occupation. With the occupation of Kharaneh IV spanning the gap between the end of the cold/dry episode of the Late Glacial Maximum (*c*. 23,000 cal. BP) and the warmer/wetter phase of the Bølling/Allerød (*c*. 15,000-13,000 cal. BP; e.g. Robinson *et al.* 2006) there is evidence that Kharaneh IV likely experienced both of these extremes. Moreover, the mid-occupation layers at Kharaneh IV correspond to the regional evidence from the Southern Levant that underwent warming and wetting periods during this general timeframe (Bar-Matthews *et al.* 1999). My results also suggest that Kharaneh IV may have local patterns of wetter and dryer periods that did not reflect what was occurring at continental or global scales. At these broader scales, the time of Kharaneh IV's occupation is thought to be a period of increasing precipitation (Bar-Matthews *et al.* 1997; Jones *et al.* 2007; Robinson *et al.* 2006; Enzel *et al.* 2008), yet we found significant evidence of fluctuations in water stress consistent with environmental drying and wetting. This contrast demonstrates that sometimes broader-scale climate data fail to represent local environmental conditions and that site specific information can be key to understanding temporal environmental change and human-environment interactions.

With this fluctuation of environment in mind, access to water, and the multiple subsistence opportunities associated with it, seems to have been an essential factor in

the attractiveness of hunter-gatherer sites (Tsatskin and Nadel 2003). Our results suggest that water stress played a role in the attractiveness of Kharaneh IV to the local hunter-gatherer populations as well as the local wildlife. This is reflected in the potentially lower frequency of use of the site at the very earliest stages of occupation when water stress was high, reduced water stress during periods of intense occupation, and an increase in water stress toward the end of the site's occupation. These results are consistent with both the frequency of dense floors and occupation layers during times when our data suggest lower water stress, but also with zooarchaeological analysis of prey types which suggest periods of all-season use of the site (Martin 2010; Jones 2012) that also coincide with indicators of low water stress from stable carbon isotopes.

My analysis is based on examining the relative change within the site. Thus, it only reflects change within each species studied, and cannot be compared with isotopic values from other sites unless, in the future, the same species are found in abundance and analysed, or only relative changes are compared. Therefore, it would be unwise to use the values reported here as a baseline. However, as a relative measure of wetter versus drier periods for a single site, I argue that this method has considerable potential.

It needs to be acknowledged that only limited samples were available to perform these analyses on. All material that was available during the duration of this PhD was fully employed. In an ideal situation, one would have access to carbonised, identifiable seeds from multiple deep trenches with continuously dated stratigraphy. Under these circumstances it would be possible to compare and strengthen these findings and confirm if they were consistent throughout the whole site. Larger samples would also render inferences less sensitive to being confounded by spatial heterogeneity in water availability, which is important since this site was likely situated in a mosaic landscape with multiple microhabitats (Ramsey and Rosen 2016). Adding to this, having access to identifiable, carbonised seeds from dated and stratigraphically sequential contexts from one or multiple contemporary archaeological sites in the region or neighbouring sites would greatly strengthen our potential environmental interpretation. However, no other such sites exist, with the exception of Wadi Jilat 6, which had no viable material for isotopic analysis due to the low number of seeds and

low frequency of species level identification (personal correspondence and re-examination of material with Sue Colledge).

An added, and unexpected, benefit of doing stable carbon isotope analysis on wild species is that in many cases the photosynthetic pathway of individual wild plants is not always known, published or available and such analysis can provide basic physiological information. For example, my results have confirmed that *Nitraria schoberi* is a C_3 plant, while the *Atriplex* species used here was a C_4.

It is extremely important that we increase and continue to collect as many stratigraphically secure soil samples as possible for archaeobotanical analysis, so that the frequency of these early sites with usable material will increase. It is only with flotation and full archaeobotanical analysis of the species present that we will decrease the current paucity of available data. And we must not forget that the need for systematic sampling of archaeobotanical samples is compounded by the requirement to use single species that span the entirety of the occupation for stable carbon isotopic analysis, so that $\Delta^{13}C$ change can be observed over time. Additional investigations that grow identified wild species under controlled conditions to examine variation and responses to water stress directly are also needed (e.g. Flohr *et al.* 2011; Wallace *et al.* 2013), and for this archaeobotanists should increase collaborations with plant ecologists and physiologists. Further experimental work is also needed so that we can better understand how stable carbon isotope levels vary between individual parts of plants, and even within a single pod of seeds (Fiorentino *et al.* 2015). Homogenizing large numbers of seeds can help to overcome this variability (Fraser *et al.* 2013b), however, this is not sensible for archaeobotanical material which is likely limited. This problem is compounded when dealing with sites, like Kharaneh IV, inhabited by hunter-gatherers, as most seed remains are from wild plants with small seeds, meaning more seeds are needed than for analysis with remains from agricultural periods.

Overall, despite the small sample sizes, the analysis of carbon isotopes reveals a pattern of fluctuating water stress for the plant community surrounding Kharaneh IV that is roughly correlated with patterns and intensity of occupation, suggesting an interaction between resource availability and site attractiveness. While the study

shows the difficulties and limitations of applying these methods to pre-agricultural sites, it also demonstrates the considerable potential in helping us to understand local environmental conditions that may not be reflected in broader-scale reconstructions.

Chapter 12. A discussion of combining traditional archaeobotanical methods with stable carbon isotopes

12.1. Introduction

Humans interact with local environments, yet palaeoenvironmental reconstructions are often carried out at broad regional or global scales. Spatial heterogeneity in climate and catchment conditions means that such palaeoenvironmental evidence may not fully represent the conditions at local sites and, therefore, may not provide an accurate setting for the context of human activities and human–environment interactions. As outlined in the introduction and in the title of this thesis, the aim here has been to tackle this challenging issue by combining multiple approaches. Here, I discus how I have combined multiple methodologies, in this case traditional archaeobotanical methods paired with stable carbon isotopes, to better understand change in local palaeoenvironments at Kharaneh IV. Combined, the archaeobotanical and the stable carbon isotopic data provide new and exciting data with which to examine the local palaeoenvironmental information from Kharaneh IV. These new data tell us a more nuanced and complete story than previously available about how this hunter-gather site existed during periods of fluctuating water stress.

12.2. A palaeoenvironmental recap

Palaeoenvironmental techniques generally consider broad scales and resolutions in both space and time. Spatial scales tend to be regional to global and temporal scales generally deal with centenary resolutions at best, though some techniques and conditions, like varved lacustrine sediments and dendrochronological sequences, can give us remarkable annual resolution (Birks *et al.* 2014). To briefly re-cap the environmental background section detailed in Chapter 3 of this thesis, the occupation of Kharaneh IV spans the transition between the end of the cold/dry episode of the Late Glacial Maximum and the warmer/wetter phase of the Bølling/Allerød (e.g. Richter *et al.* 2013; Robinson *et al.* 2006; Bar-Matthews *et al.* 1999). Just before, and during, the earliest levels of occupation at Kharaneh IV (the Early Epipalaeolithic stages) there is evidence of a substantial wetland at the site. At least to some degree during these early phases of occupation at Kharaneh IV, water availability appears to have been relatively constant (Jones *et al.* 2016a, 2016b; Maher *et al.* 2016).

At the broader regional scale, the Epipalaeolithic period is thought to have had increased precipitation levels (Bar-Matthews *et al*. 1997; Jones *et al.* 2007; Robinson *et al.* 2006). In the Levant, prior to the establishment of Kharaneh IV (prior to 19,830 cal. B.P) we also see the highest water levels in Lake Lisan and other regional terrestrial water bodies, followed by a decline at about 20,000 cal. BP (Torfstein *et al.* 2013; Roberts 1983; Roberts *et al.* 2011; Çağatay *et al.* 2014). In addition to this, in the Southern Levant, periods of warming and wetting were taking place (Bar-Matthews *et al.* 1999). Speleothem and stromatolite data suggest that rainfall was lower in the area of the Dead Sea Valley between 25 and 18 ka BP (Sorin *et al.* 2010). Moving further afield, these trends in the Levant also fit with Robinson *et al.*'s (2006) models of a fluctuating climate in the Levant and Eastern Mediterranean.

My archaeobotanical results (Chapter 6) demonstrated changes in the density and diversity of wet and dry species, suggestive of environmental change and a fluctuating environment at Kharaneh IV. However, the specificity and reliability of these inferences is limited by small sample sizes, taphonomic factors, and low ecological resolution of the data. This lack of specificity, coupled with difficulties in identifying poorly preserved, sparse Epipalaeolithic remains to low taxonomic levels (e.g. species), made inferring specific environmental conditions and the extent of environmental change from the taxonomic composition of plant communities difficult.

The stable carbon isotope analyses reported herein demonstrated that Kharaneh IV likely experienced variable water stress throughout its *c.* 1,200 years of occupation. Despite being challenged by similar factors to those encountered while doing the archaeobotanical analysis (lack of continuously present species, which limited the number of samples available for isotopic analysis), the most robust results from the *Nitraria schoberi* samples suggested strong evidence for fluctuating water stress and pointed to a relatively dry ending to the occupation of the site. However, while *N. schoberi* was the most abundant species I could analyse in terms of samples and stratigraphic coverage, the sample size was still relatively small, increasing the chances of spurious patterns emerging, which reduces the reliability of the inferences I can make.

12.3. Synthesising archaeobotanical and isotopic evidence: a case of success

Changes in the structure of ecological communities and in the isotopic signature within species provide two lines of evidence for the changing nature of water availability at Kharaneh IV. The Kharaneh IV data are constrained by the reality that it represents only a partial record of the ecological community but nevertheless, still represents a record of the environment surrounding the site. Ecological theory proposes that changes in environmental conditions, like water availability, should alter the environmental filters structuring a community, inducing changes in species' composition (Weiher *et al.* 1998). Thus, drier conditions should lead to an increase in the richness of 'dry' species, relative to 'wet' species and a higher ratio of wet to dry species can be taken as indicative of wetter conditions.

Changes in water availability can also alter the water stress experienced by individual species, even in the absence of species turnover or changes in community structure. Many species have broad water tolerances, so changes in water availability through time may be insufficient to induce community turnover. However, as water conditions change, even generalist species should experience varying levels of water stress, which can leave a signature in $\Delta^{13}C$. Thus, changes in isotopic ratios may indicate fluctuations in water availability that are insufficient to induce community turnover.

Figure 12.1. shows $\Delta^{13}C$ values for *Nitraria schoberi,* the species for which I had the most extensive and complete sampling record, across stratigraphic zones, overlain with the ratio of 'wet' species richness to 'dry' species richness. Although the scales of the axes are different, the similarity in the patterns is clear: both $\Delta^{13}C$ and wet:dry ratios indicate an early period of dryness (in zone B3), a wetter period through the middle stratigraphic zones, and then a pronounced period of dryness at the end of Kharaneh IV's period of occupation. The wet:dry ratio data are more complete through stratigraphic zones than the *N. schoberi* data and thus provide more detailed temporal information on the extent of the wet and dry periods.

Combined, these data indicate that the wettest period was predominantly during the time of stratigraphic zones B2 and B1, and by the time zone A2 and A1 were occupied, the site had already begun drying out. Set within the broader archaeological

context of Kharaneh IV, Zone B2 has the highest density of living surfaces found on site (Maher *et al.* 2012), which paired with this evidence for the relatively low water stress, suggests this may have been a time of "prosperity". This evidence of a higher frequency of living floors and dense accumulation of cultural material within Zone B2 suggests that human activity increased during wetter periods.

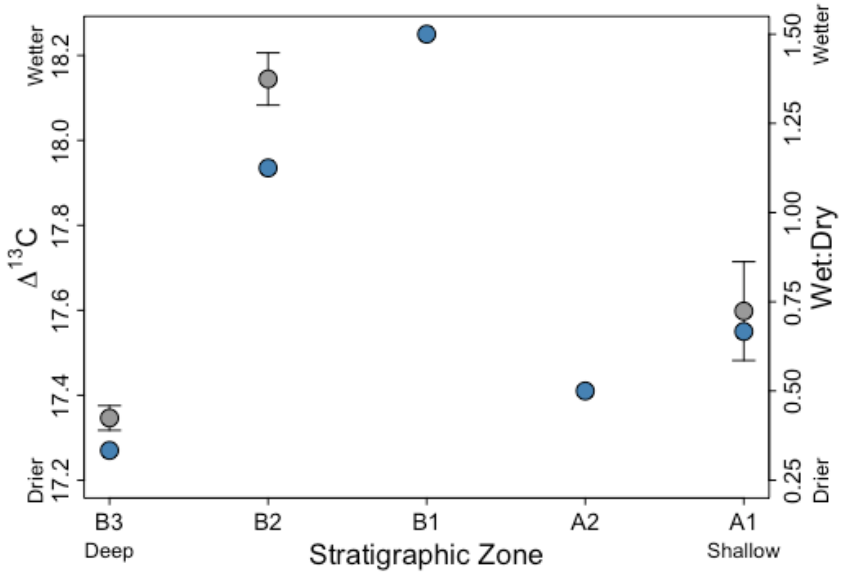


Figure 12.1. Archaeobotanical and isotopic evidence for changing water stress at Kharaneh IV across stratigraphic zones. The left Y-axis and grey symbols show mean $\Delta^{13}C$ of *Nitraria schoberi* seeds for each stratigraphic zone; error bars depict standard errors. Larger values of $\Delta^{13}C$ indicate wetter conditions. The right Y-axis and blue symbols show the ratio of the number of taxa preferring wet habitats to the number of species preferring dry habitats. Thus, values greater than 1.0 indicate more 'wet' species than 'dry' species.

The dual investigative approach pursued here, with one branch based on isotopes and the other on archaeobotanical assemblages, provides strong and consistent evidence for fluctuating water availability at Kharaneh IV. This dual approach also reduces the possibility that observed patterns could be due to chance events, or sampling effects. For example, given the relatively small sample sizes obtainable from the site, variation in water stress of a single species, like *N. schoberi*, could arise due to factors other than changing climate conditions. To illustrate this, water availability will always be spatially and seasonally heterogeneous, which could result in seeds from a water-stressed individual from a drier microhabitat or during the dry season being preserved. Such an event, given my small sample size, could give the appearance of a

drier period in Kharaneh IV's history. However, such a chance event would not be replicated in the archaeobotanical assemblage data, which includes multiple species and thus would be far less susceptible to chance sampling events. Alternatively, as discussed above, assemblage-only data may fail to detect smaller magnitude changes in water availability, which could lead to a lack of variation in assemblage data. Thus, the strongest evidence for shifting water regimes arises, as found here, when intraspecific and interspecific patterns show consistent patterns. Future work, particularly on similar hunter-gatherer sites, where local palaeoenvironmental conditions are of utmost interest, and should consider both isotopic and assemblage-based analyses as how these two measures coincide or differ can provide deeper insight into past environmental variability.

12.4. Putting the results into context

My results are consistent with much of the current thinking regarding the palaeoenvironmental conditions during Kharaneh IV's occupation (a wetter beginning, followed by a drying out), yet they do not align completely. It has been suggested, based on sedimentary analysis, that water availability was relatively high and constant through the mid period of Kharaneh IV's occupation (Jones *et al.* 2016a, Jones *et al.* 2016b; Maher *et al.* 2016), and my results also suggest this pattern. However, my results indicate that drier, more arid, conditions may have dominated during the earliest period of occupation at Kharaneh IV.

Intriguingly, my two lines of evidence (isotope and habitat preference analysis; see Figure 12.1) provide a completely opposite interpretation to Ramsay *et al.* (2016)'s phytolith grass, short-cell comparison ratios of an assemblage from Kharaneh IV (Figure 12.2). Their work showed a wet Early Epipalaeolithic phase in Area B, where both my lines of evidence from the exact loci (031, 030- Stratigraphic Zone B3) suggested that this early occupation was relatively dry. I am unsure of the exact location of Ramsay *et al.*'s (2016) stratigraphically higher samples from Area B (227 through to 187), but if we interpret these as being on top of the earlier samples as the publication suggests, they appear to fall in the later occupation phases of Area B. If this is the case, then here again, their results contrast with mine and suggest this was a drier phase, while my samples from the upper/later parts of Area B (Zone B2 and B1), showed this to be a relatively wet phase at Kharaneh IV. As we move into the Middle

Epipalaeolithic Area A of Kharaneh, again Ramsay *et al.'s* (2016) results differ. Here, my samples from these loci (004 and 008- Zone A2) showed evidence of this being a relatively wetter period while Ramsay *et al.'s* evidence points in the complete opposite direction (compare Figure 12.1 and Figure 12.2). For my stratigraphic zone A1 and Ramsay *et al.*'s loci-100-105 again our results differ. My evidence suggests this to be relatively drier at the end of occupation, while their results suggest this period to have increasing precipitation.

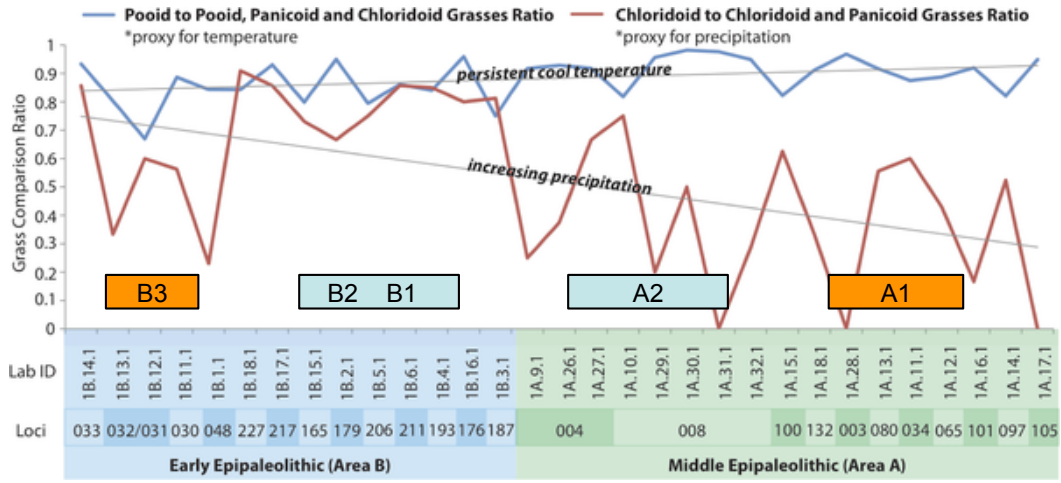


Figure 12.2. Placement of my stratigraphic zones along Ramsay et al's (2016) stratigraphic sequence of grass ratios, reconstructing temperature and precipitation at Kharaneh IV. In Ramsay et al.'s analysis, higher ratios indicate cooler temperatures (blue line) and drier conditions (red line). In contrast, my isotope and ecological analysis found Stratigraphic Zones B2, B1 and A2 (blue) were wetter and Zones B3 and A1 (orange) were drier (see Figure 12.1).

The contradictory results of Ramsay *et al.*'s (2016) analysis and the analyses I have presented open a debate on the environmental history of Kharaneh IV. Key to resolving this debate will be to determine why my analysis, based on multiple lines of evidence using species' ecology and community composition as well isotopic change within species, contradict Ramsay *et al.*'s (2016) results. It is possible these measures capture signals from different scales (local or regional) with phytoliths capturing broader trends, while the seed-based analysis capture locality-specific information. It is also possible that shifting heterogeneity in water availability around Kharaneh IV can produce differing signals in sparse samples. Further investigation will undoubtedly produce additional detail on the history of water stress at Kharaneh IV,

as well as provide valuable insight into the environmental components capture by different proxies.

My data provide additional evidence for the proposed drying out of Kharaneh IV towards the end of occupation (Maher *et al.* 2012; Jones *et al.* 2016ab). However, previous work has also suggested that substantial wetland was present just prior to, and at the beginning of Kharaneh IV's occupation (Jones *et al.* 2016ab; Maher *et al.* 2016). In contrast, my combined isotopic and ecological archaeobotanical analyses suggest that this early stage was relatively dry, with water availability increasing during the heaviest periods of activity. The consistency of the isotopic and archaeobotanical data reduces the likelihood that the detected early dryness is simply a sampling artefact, but I cannot completely exclude the possibility. Nonetheless these different lines of evidence open up a debate around the relative water availability at the very initial periods of Kharaneh IV's use that would require additional study and evidence. One possibility, alluded to by Jones *et al.* (2016a) is that just prior to occupation, it may have been too wet for consistent human exploitation, but initial drying phases facilitated human use of the area. This could have resulted in spatial heterogeneity of wet-dry conditions, leading to a landscape mosaic (as suggested by Ramsay *et al.* 2015, 2016). As conditions once again became wetter, the mosaic could have become increasingly dominated by wetter conditions with higher productivity that would have been more favourable for human activity. Such a sequence could explain the apparent discrepancy in the early sedimentary and archaeobotanical evidence and also their convergence during the mid-wet phases. Broader, systematic sampling (repeated application of these archaeobotanical and isotopic methods on many more samples from throughout the site) designed to capture landscape scale heterogeneity could be used to help shed light on this possibility.

12.5. Setting Kharaneh IV in a regional climatic context

As discussed above, at a regional and global scale, the early Epipalaeolithic is thought to have been a time of increased precipitation (Bar-Matthews *et al.* 1997; Jones *et al.* 2007; Robinson *et al.* 2006). My results suggest that this broad generalisation cannot be applied ubiquitously to individual sites. My results clearly demonstrate that at a local scale, Kharaneh IV existed in a time of fluctuating water stress. In particular, the archaeobotanical and isotopic results combined indicate local relative water stress in

the final phases of occupation at the site, when the regional trend suggests this should be wet. This discrepancy once again could reflect spatial heterogeneity in palaeoenvironmental conditions that is lost at coarser grains of analysis. However, it also illustrates an important consideration with respect to the reference point used for estimates of relative water availability. A wetter global period may simply indicate that mean 'wetness' conditions have increased overall, but does not prohibit fluctuations in the relative water availability at shorter time scales that would still have implications for vegetation and ecological communities that may be important for human populations. Thus, overall, this contradiction between global and local palaeoenvironment perceptions demonstrates that broader-scale climate data can sometimes fail to represent the local, site-specific, reality, which is a key factor in integrating environmental evidence with human occupation.

When trying to understand the climate and culture of hunter-gatherers sites, we need to remember that for the day-to-day reality of a hunter-gatherer, what matters is the local environment that they live in and use. It is essential that, when interpreting human-palaeoenvironment interaction, we keep in mind that the individual hunter-gatherer is unaware of what the climate is like 200 miles away, or even in the next mountain range, nor what it was like in the far past or what it will be like for future generations. We must also remember that, for hunter-gatherers, the scope for responding to and interacting within their unique ecological environment/niche is constrained by resource availability and knowledge based on generational memory (see Butzer 1971, 1982; Smith 2007, 2011; Zeder 2012; Byrd *et al.* 2016). In Jones's (2013) discussions on quality vs. quantity of water, he touched on a few essential points that we must keep in mind when discussing the presence of water at Kharaneh IV. Jones (2013) suggests that the continued presence of people in a location can be used as a proxy not only for water availability, but for potable water availability. Applying this train of thought to Kharaneh IV, we can then assume that any evidence of occupation on site means that there was at least some sort of potable water nearby the site during times of human use. They would have moved on to other sites (perhaps only seasonally) as the area dried and water became more stagnant without the frequent re-charge of the water sources by rain.

12.6. Liquid prosperity: the realities of water for hunter–gatherers

Jones *et al.* (2016a) have hypothesised that in the time period leading up to the establishment of Kharaneh IV, during the drying episodes affecting the region around 20 ka BP (the early Epipalaeolithic including Zone B3 and lower at Kharaneh IV), the ancestors of the Kharaneh IV hunter-gatherers were starting to use and occupy the margins of the productive and expansive wetland in the Azraq Basin. Jones *et al.* (2016a) suggest that as the water levels continued to drop, the wetland edge site of Kharaneh IV itself became a more attractive and accessible place in the landscape and this is when it experienced increased use until the water became too sparse, or too far away, to support the population. My results are consistent with this hypothesis but add nuance, suggesting that, rather than a consistent gradual drying throughout Kharaneh IV's occupation, there was a mid-period of wetter conditions which may have further facilitated human exploitation.

Interpretations of palaeoenvironmental–human interactions at Kharaneh IV place substantial reliance on the importance of water for hunter-gatherers, and societies more broadly. This assumption is well grounded and, as Taylor (1964) suggested, hunter-gatherers are "tethered to water"; water is the most basic and necessary resource for any human (see also Mithen 2011; Jones 2013; Binford 1980; Ramsay *et al.* 2015; Butzer 1982; Kelley 2015; Winterhalder 2001). Ramsay *et al.* (2016)'s phytolith studies also concluded that, at Kharaneh IV, subsistence activities and the success of the site was chained to the reliable wetlands it was situated in. This suggests that without the wetlands and access to water, the site would have become no longer suitable to its users, which is consistent with the evidence of end-of-occupation drying in the archaeobotanical and isotopic record.

Taking the sedimentary, archaeological and archaeobotanical findings together suggests that one of the key factors in drawing the users to the Kharaneh IV site was water availability. Wetlands may become even more important when surrounding conditions worsen, creating a haven of local abundance amongst a situation of regional scarcity (Ramsay *et al.* 2015; Ramsay and Rosen 2016; Ramsay *et al.* 2016; Copeland and Hours 1989; Cordova *et al.* 2013; Garrard and Byrd 2013; Jones and Richter 2011; Nicholas 1998, 2007, 2013). Byrd (1994) suggested that settlement, particularly in the Eastern Levant, has been seen to concentrate around wetlands (see

also Cordova *et al.* 2013; Jones and Richter 2011; Olszewski 2000; Richter *et al*. 2013; Rosen 2012, 2013). The location of Kharaneh IV, within the wetlands of the Azraq Basin, has long since been suggested as a desert refuge (Copeland and Hours 1989; Cordova *et al*. 2013; Garrard and Byrd, 2013; Jones and Richter, 2011), which supports this assumption.

For hunter-gatherer communities, wetlands can be an important and primary source of perennially available resources, such as food, fuel, building materials and water (Nicholas, 1998, 2007, 2013). Wetlands provide a reliable environment, and living at the edge of littoral marshes and shallow water environments, such as those present during the occupation of Kharaneh IV (Jones *et al.* 2016a), would have been productive (Ramsey *et al.* 2015). Such environments would harbour plant food sources, such as tubers and bulbs, among others (see Chapter 9; Hather 2000, 1988, 1993; Wrangham 2009; Ramsay and Rosen 2016, Ramsey *et al.* 2016). The hunter-gatherers at Kharaneh IV could have survived and thrived for many generations (possibly 10+) in large part because of the reliable resources the wetland had to offer. While hunter-gatherers are by their very nature flexible, their actions and choices are based on their relationship with their ecological and cultural environment. Nonetheless, they are intensively tied to their resources (Ramsay and Rosen 2016; Lee and Devore, 1969; Binford, 1980).

Subsistence at Kharaneh IV may have been enhanced because, as Ramsay *et al.* (2016) suggested, the occupation of the site coincides with a period of particular prosperity. The productivity of the wetland may have permitted the inhabitants of Kharaneh IV to supplement the readily available basic resources such as the plentiful, local gazelle who also benefited and thrived due to the local wetlands (Martin *et al.* 2010; Jones 2012) with riskier resources obtained from travelling further afield into the neighbouring steppe parkland (Ramsay *et al.* 2016). Such risks could have been taken, and these resources exploited, because they had their basic needs (access to a full larder of basic subsistence supplies) met at home, within the wetland at Kharaneh IV. This behaviour suggests that the hunter-gatherers of Kharaneh IV were able to use the year-round resources (such as underground storage organs) of the wetland as well as strategic foraging beyond the safety of the wetland (Ramsay *et al.* 2016) and this

could have allowed them to settle for longer in larger groups, resulting in the accumulation of large amounts of cultural debris at the site.

A fluctuating climate would of course impact the resources available to the hunter-gather population at Kharaneh IV and in the Azraq Basin. For the Levant region, Rosen and Rivera-Collazo (2012) have outlined a potential adaptive strategy that suggests hunter-gatherers would have alternated between resources in reaction to changes in their environment. This sort of adaptive strategy could have also been particularly important during dry fluctuations at Kharaneh IV when there would have had to have been some sort of shift in resource exploitation as one plant or animal source died out or became less common or productive. For the 1,200 years of occupation at Kharaneh IV, these were successfully flexible hunter-gatherers who were able to make the most of their landscape and exploit it during both the wetter and drier phases. This is also supported by Ramsey *et al.* (2016), who suggested that during warm/wet phases people were likely more willing to go outside their local environment and take calculated risks to exploit plant resources further afield. Conversely, during cold/dry phases they would have stuck closer to home and relied more heavily on the local wetland resources. However, diminishing wetland reliability could also stimulate riskier foraging behaviours if it became necessary to travel further afield to sustain basic requirements. This suggests that 'risky' foraging behaviours may not arise only during periods of wetland prosperity, but rather show a hump-shaped relationship. Risky foraging into the steppe could have been prevalent when conditions were favourable (Ramsay *et al.* 2016), and then reduced as wetland conditions declined, followed by an increase again as wetland deterioration continued. Under such a scenario, convergence in risky foraging behaviours would be underlain by different cultural and environmental drivers, with foraging riskily in times of plenty a voluntary activity (possibly linked to status), but in lean times such behaviour would be driven by necessity.

Potential foraging ranges for the users of Kharaneh IV have been examined by Byrd *et al.* (2016). Their publication offers a wide range of investigations into potential trading routes, which extended as far as the Mediterranean and Dead Sea (Allcock 2009), as well as modelling potential daily and annual settlement organisation of the site's users. They have suggested that Kharaneh IV had two potential foraging

territories that extended as far as the Azraq springs in the centre of the basin. However, the one-day foraging ranges for Kharaneh IV did not extend beyond the dry steppe. Byrd *et al.* (2016) also predict that the annual settlement extended either near or beyond their maximum two-day foraging range, which would have allowed them to capitalize on different seasonally available resources from both the wetland and the aforementioned riskier periphery. Adding to this, they have also suggested that due to the smallish nature (in comparison to Kharaneh IV) of other sites in the Levant that may have been used during these seasonal trips away from Kharaneh IV, the population may have split up into smaller residential groups. Outlining barriers of the dry steppe to the north and south of the site, Byrd *et al.* (2016) offered two scenarios. The inhabitants may have travelled east towards freshwater riparian habitats of the Azraq Oasis or, alternatively headed west into the wetter woodland steppe or park woodlands that would have offered a varied range of different plants, such as grasses, legumes and nuts like pistachio and almond.

At Kharaneh IV, especially during its prime (Zones B2, B1), it is conceivable to suggest that water availability would have dictated the timing and frequency of undertaking seasonal foraging trips away from the site to either the wetlands in the east, the western woodland steppe, or park woodlands. In particular as the water stress increased at Kharaneh IV (Zones A2 and A1 see Figure 12.1), it would seem logical that the regularity of leaving the site in search of other, more plentiful, resources would increase, due to necessity-driven risky foraging. As resources dwindled, it would also make sense that they would divide up into smaller groups in search of seasonally available but spatially patchy resources elsewhere, rather than aggregate in a single large settlement. Of course, other factors could also facilitate the breakup of single large settlements, such as rising territoriality (Whallon, 2006) or mating group pressures (Pearce, 2014). However, these are not directly linked with water stress, though as resources became scarcer, ecological and evolutionary theory predicts competition will increase for territory and mates (Darwin 1859).

12.7. Drying up and moving on

Access to dependable resources was likely a key factor in the transition between subsistence and sedentisim in the Near East (Savard *et al.* 2006). Kharaneh IV's existence and success (at least for the 1,200 years it was around), is likely due to it

being located in the right ecological context at the right time with access to reliable resources. A combination of access to a mosaic environment, with a consistent source of food and other resources, would have contributed to the site's inhabitants' ability to thrive (Ramsay *et al.* 2016).

The importance of resource abundance and stability for the development of sedentisim is further augmented by the abandonment of Kharaneh IV. The evidence for late occupation water stress in the isotope and archaeobotanical assemblage data I uncovered is consistent with the hypothesis that environmental prosperity did not last at Kharaneh IV, but rather ended when the site began to dry out. This evidence bolsters the theory of resource driven abandonment at Kharaneh IV due to a decline in basic resources. Both Jones *et al.* (2016) and Garrard and Byrd (2013) have suggested that settlements like Kharaneh IV, and its neighbouring coeval site of Wadi Jilat 6, may have 'followed the water' and shifted away from the drying areas south of the Azraq Oasis in the western portion of the basin by the end of the Middle and Late Epipalaeolithic. The multiple lines of water stress evidence presented in this thesis now also support this suggestion. It is plausible to suggest that, as water stress increased, the inhabitants of Kharaneh IV continued to 'go with the flow', and followed the water as it retreated across the landscape, demonstrating a level of resilience to environmental change through an ability to track the waters, and the plant resources they provided, as their levels receded and fluctuated (Jones 2016a).

Chapter 13. Conclusions

The main aims of these investigations were twofold: firstly, to examine and analyse the plant remains uncovered thus far from the Kharaneh IV excavations, and in doing so, create a database and seed catalogue of the species found, enlarging thus the Epipalaeolithic dataset for the Levant and contributing new information on hunter-gatherer lifeways; secondly, to use stable carbon isotope analysis to reconstruct relative water stress during the occupation of the archaeological site and test this methodology for the first time on pre-agricultural macrofossils.

The archaeobotanical data and analysis from Kharaneh IV conducted here provide as many questions as they do answers in relation to both environmental and archaeobotanical reconstructions. A common theme arising from both branches of enquiry is that there are substantial inferential limitations linked to sparse sampling, identification, taxonomic and ecological resolution that may be pervasive for Epipalaeolithic sites. Clearly, all answers cannot lie in the seed remains alone. However, when coupled with other archaeobotanical information (e.g. phytoliths; Ramsey *et al.* 2016, Ramsey and Rosen 2016), geological investigation (Jones *et al.* 2012, 2016), and archaeological finds (Maher *et al.* 2012) from Kharaneh IV, along with a comparative approach with neighbouring sites, a more complete picture both of environmental and archaeobotanical variability has been drawn. Kharaneh IV's archaeobotanical data is now contributing substantially to our knowledge and understanding of Epipalaeolithic foraging regimes. The new data presented here contribute to the argument that hunter-gatherer subsistence systems, particularly in the Levant, were highly adaptive (Rosen 2007, Rosen and Rivera-Collazo 2011, Ramsey et al. 2017; Ramsey and Rosen 2015). Based on the continuous occupation sequences and despite the now confirmed fluctuating water stress at the site throughout its occupation, the hunter-gatherer users responded to change and continued to exploit the locally available resources by varying their resource choices. Future analysis of the samples from inside the hut structures will undoubtedly offer us greater insight into the domestic lives of the Kharaneh IV hunter-gatherers. Nonetheless the material included here, along with the potential plant material that remains to be uncovered at

Kharaneh IV, makes it a key archaeobotanical site of the Epipalaeolithic in the Levant.

Excavations are scheduled to continue for the foreseeable future at Kharaneh IV and continuing study of the evidence collected from these and past field seasons (including a re-examination of Muheisen's finds) will help us answer important questions surrounding this settlement site. Undoubtedly this will lead to further discussion about how sites like Kharaneh IV demonstrate that sedentism and agriculture may not necessarily be linked and can occur independently (Barker 2006) and that the process may have begun earlier than previously thought.

These discussions will draw on the archaeobotanical research presented here and as more archaeobotanical samples become available (including the results from the on-going anthracological analysis by Eleni Asouti) from the excavations, we will be able to compare the nature of the activity inside versus outside the huts and investigate how these early huts compare to later architectural features on site and temporally within the region.

The stable carbon isotope analysis of wild seed samples combined with traditional archaeobotanical analyses of the available plant remains from the pre-agricultural site of Kharaneh IV have demonstrated that it is possible to use these data as a proxy for relative changing water availability. My results have demonstrated that Kharaneh IV experienced variable water stress throughout its occupation. These Kharaneh IV results, therefore acts as evidence that sometimes, broader-scale climate reconstructions (Bar-Matthews *et al.* 1997; Jones *et al.* 2007; Robinson *et al.* 2006; Enzel *et al.* 2008) fail to represent local conditions and that site specific information can be key to understanding temporal environmental change and human-environment interactions.

Overall, despite small sample sizes, the analysis of carbon isotopes reveals a pattern of fluctuating water stress for the plant community surrounding Kharaneh IV that roughly correlated with patterns and intensity of occupation, suggesting an interaction between resource availability and site attractiveness. While the study shows the difficulties and limitations of applying these methods to pre-agricultural sites, it also

demonstrates the considerable potential in helping us to understand local environmental conditions.

Combining broader palaeoenvironmental and finer-scale archaeological techniques highlights how questions of scale and resolution can complicate, or even mislead, inferences of human–palaeoenvironmental interactions. In the case of Kharaneh IV, the global and regional climate records might not be directly applicable to the local site and could give an incomplete picture of the conditions actually experienced by the site's inhabitants. Supplementing regional trends with multiple lines of site-specific evidence can offer a balance between the local and the regional to give a more complete picture of the challenges and opportunities that environmental conditions provided to hunter-gatherers. Furthering the potential of such enquiries will require deeper collaboration between archaeologists and palaeoenvironmental scientists.

For Kharaneh IV, as with all hunter-gatherer sites, the 'local' is of the utmost importance. This is the scale of human consequence that defines peoples' experiences and their responses. However, as the evidence of foraging ranges (Byrd *et al.* 2016) and potential tracking of retreating water resources across the Azraq Basin landscape signify, the local cannot be completely divorced from the regional (Jones *et al.* 2016; Garrard and Byrd 2013). Here, I have treated the 'local' as a way to understand the environments that hunter-gatherers faced which may influence their exposure to regional-scale pressures. This dual approach has allowed me to interpret my data across and between the scales over which humans and their environments interact.

A challenge we face when developing such interdisciplinary approaches and interactions is that we are highly dependent on the information made available to us from the contexts our samples come from. Thus, the success of such endeavours lies heavily in the hands of the initial excavations and the data they produce. Such data can be so vast that there is a risk of important contextual information being missed or de-emphasised due to the need to prioritise the different interests and goals within excavational constraints. Thus, integrated planning and input from the complete range of specialisms is necessary to ensure that data are suitable for archaeological, archaeobotanical, palaeoenvironmental and other types of analysis. For Kharaneh IV in particular, further analysis of samples associated with more household/ cultural

activity, like the hut structures, is needed. Further information on a range of contexts related to human activity is essential before the potential of the archaeobotanical analyses at Kharaneh IV can be fully realized. Additionally, the new data presented here combined with the studies that have and will come out of future excavations at Kharaneh IV, bolster Maher *et al.* (2011)'s call for more precise chronological data (Richter and Jones 2013) and for the integration of more local palaeoenvironmental data at archaeological sites (Jones *et al.* 2016).

Linking environmental and cultural change remains a core challenge when examining the Epipalaeolithic, where the complexity of factors potentially affecting human–environmental interactions is vague at best. Although extensive work continues, approaches to this challenge remain both theoretically and methodologically wide open. At Kharaneh IV, the use of proxies and archives (isotopic and archaeobotanical) from the site itself, coupled with those from the Azraq Basin, and the wider region contribute to this addressing this dearth. These data help to link our understanding of palaeoenvironment and hunter-gatherers' interactions in the context of local and regional pressures, especially responses to shifting water availability.

Together, the evidence found in this thesis suggests that survival for hunter-gatherers at Kharaneh IV depended immensely on their ability to adapt to changing ecological opportunities as well as to access the most essential resources, all of which are linked to water. It is this necessity, at the most fundamental level (Taylor 1964) for water that likely first drew people to the site of Kharaneh IV, and is certainly one of the driving factors that coincides with why there is such a large, artefactually dense site.

Access to water, and the multiple subsistence opportunities associated with it, is an essential factor in the attractiveness of hunter-gatherer sites and my results suggest that water stress would have played a role in the attractiveness of Kharaneh IV. This is reflected in the potentially lower frequency of use of the site at the very earliest stages of occupation when water stress was high, reduced water stress during periods of intense occupation, and an increase in water stress toward the end of the site's occupation.

The available water at Kharaneh IV in conjunction with the evidence of dense cultural material (Maher *et al.* 2012) and the faunal records showing multi-seasonal use of the site (Martin *et al.* 2010; Jones 2012) suggest that water availability likely facilitated year-round congregations at the site. The coincidence with the end of intense occupation with the drying out of the local environment demonstrates the fundamental importance of environmental conditions for hunter-gatherers, though it is possible that the site remained in use to some degree during seasonally wetter periods, as the site would have likely held sentimental/spiritual/memories/stories for the users as a known hunting or congregation spot.

At Kharaneh IV, and at all Epipalaeolithic sites, it is extremely important that we continue to collect as many stratigraphically secure soil samples for archaeobotanical analysis as possible, so that the frequency of these early sites with usable material/ data will increase. It is only with flotation and full archaeobotanical analysis of the species present that we will decrease the current paucity of available data. The need for systematic sampling of archaeobotanical samples is compounded by the need to use single species that span the entirety of the occupation for stable carbon isotopic analysis, so that $\Delta^{13}C$ change can be observed over time. Additional investigations that grow identified wild species under controlled conditions to examine variation and responses to water stress directly are also needed (e.g. Flohr *et al.* 2011; Wallace *et al.* 2013), and for these archaeologists should increase collaborations with plant ecologists and physiologists. Further experimental work is also needed so that we can better understand how stable carbon isotope levels vary between individual parts of plants (Fiorentino *et al.* 2015). Homogenizing large numbers of seeds can help to overcome this variability (Fraser *et al.* 2013b). However, this generally only applies to post-agricultural material as it is not sensible to do this with rare, and often unique material which is likely limited.

The Epipalaeolithic is still a cryptic time period for archaeologists. Not only are we trying to understand what the data tell us, we are also still trying to understand if these data are enough to identify climatically driven societal change. At this point it is likely that a data-based, theoretical model is all we can realistically ever hope to achieve. With more data like those presented here, the better and more nuanced this model will become. Approaches based on multiple lines of evidence, as used here, can help

overcome the limitations of Epipalaeolithic data and, for Kharaneh IV, have revealed intricate and changing links between hunter-gatherers and their landscape. These data respond to the call for a bottom up, data-driven approach to studying human – environment interactions and the use of local-scale of investigation, rather than large-scale regional explanations of change (Jones *et al.* 2016). My work adds to the argument that it is important to diversify not only across scales but also across sources of evidence, such as isotopes and traditional archaeobotanical analyses, to overcome the limitations of Epipalaeolithic data and provide new insight into how these people interacted with their changing environment.

On a final note that links the past with our future, even today Kharaneh IV and the broader region of the Near East is predicted to have increased frequency and intensity of droughts as cold season precipitation is predicted to decrease (Christensen *et al.* 2013). Palaeoclimate records, like the ones presented here, offer meaningful and applicable comparisons (Braconnot *et al.* 2012). As climate change intensifies in our lifetime, particularly in the Middle East (Gorgi, 2006), understanding how we as humans have adapted will be key to adapting our current ways. In the Near East, water is a scarce resource. The recent multi-year droughts and the poor management of water at the domestic and agricultural level have highlighted our dependency on this essential resource to maintain modern standards of living (Joodaki *et al.* 2014; Kelley *et al.* 2015). Recent studies have linked the socioeconomic effects of the droughts in Syria and Iraq (2007-2010) with the importance of water and political stability (Flohr *et al.* 2017; Gleick 2014; Kelley *et al.* 2015; de Chatel 2014; Trigo *et al.* 2010); these droughts have contributed to the massive displacement of people from rural areas in Syria. Despite all our technological advances and our greater historical and cultural awareness it is remarkable that today, just as during the Epipalaeolithic, this region and much of the world continues to be vulnterable to water stress.

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Appendix 1: Seed Recording Form

Appendix 2: Master Data Tables

13.1. Master Data Table for Area B. Additional columns are shown on subsequent pages

Kharaneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AP36	AP36	AP36	AP36	AP36	AP36	AP36
			Locus	041	046	049	050	057	065	084
			Description	orange compact sediment	dark brown stain on 047	new dark spot	new dark spot	orange deposit in new soil locus	merging brown stains	compact sediment,cut by hearth 67
			Stratigraphic Zone	1A	1A	1A	1A	1A	1A	2A
			Volume (l)	3	0.2	0.175	0.05	51	9	12
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment							
***Lepidium* sp. (fat type)**	Cruciferae	390	seed							
Cruciferae frag. (large)	Cruciferae	390	fragment							
Cruciferae sp.	Cruciferae	390	seed			2				
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed					33	69	23
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed			1		10	8	11
Chenopodiaceae	Chenopodiaceae	1621	fragment							
***Atriplex* sp.**	Chenopodiaceae	1654	seed		1	1				
***Salsola* sp.**	Chenopodiaceae	1703	seed							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed							
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment							
cf. Leguminosae (large)	Leguminoseae	2161	seed							
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed		3			53	77	27
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed					2		
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment							
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed							
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment							
cf. Cyperaceae core Type 1	Cyperaceae	8642	core							
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core							
***Carex* sp.**	Cyperaceae	8689	seed						1	
Carex sp. (mineralized)	Cyperaceae	8689	fragment							1
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed					1		
Gramineae SMALL	Gramineae	8856	fragment							
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed							
Gramineae MEDIUM	Gramineae	8856	fragment							
Gramineae LARGE >1.5mm	Gramineae	8856	fragment							
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment							
Compositae Kernels	Compositae	9947	Kernel					10	13	11
Compositae Kernels	Compositae	9947	fragment					11	33	3
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed			1		7		16
Unidentifiable (indet.) seed fragment	N/A		fragment			1		21	46	35
Unidentifiable (indet.) seed core	N/A		core							
Small seed core type	N/A		core							
Unidentifiable (indet.) Non wood frag	N/A		fragment			8		7		150
cf. Fruit flesh	N/A		fragment							
Reticulate 'Hook' fragments	N/A		fragment							
Burned masses (small)	N/A		1,2 or 5ml							
Dung like pellet	N/A		pellet							
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment							
mineralized fruit/nut shell (mineralized)	N/A		fragment							
vitrified spike/fruit?	N/A		fragment							

Khareneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AP37	AP37	AP42	AQ36	AQ37	AQ37	AQ42
			Locus	035	076	008	067	035	041	003
			Description	Light brown silty sediment -Locus containing (38)-(42), Dark Spots, beside hearth (grape contamination)	Compact Floor, beside hearth (067)	Compact light brown sediment	hearth	Light brown silty sediment -Locus containing (38)-(42), Dark Spots, beside hearth (grape contamination)	orange compact sediment	Dark brown soil with lots of charcoal
			Stratigraphic Zone	1A	2A	2A	2A	1A	1A	1A
			Volume (l)	58	28	16.6	15	192	3	15
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed				2			
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment			2		2		
***Lepidium* sp. (fat type)**	Cruciferae	390	seed				3			
Cruciferae frag. (large)	Cruciferae	390	fragment				7			
Cruciferae sp.	Cruciferae	390	seed			3				2
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed	3	4	1	791	7	3	
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	2	19	6	37	22	2	2
Chenopodiaceae	Chenopodiaceae	1621	fragment					2		
***Atriplex* sp.**	Chenopodiaceae	1654	seed		29	16	68			
***Salsola* sp.**	Chenopodiaceae	1703	seed				15			
cf. *Salsola* sp.	Chenopodiaceae	1703	seed			1	21			
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment							
cf. Leguminosae (large)	Leguminoseae	2161	seed			1				
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed	1			76	9	2	
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed					1		
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment							
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed							
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment			1		1		
cf. Cyperaceae core Type 1	Cyperaceae	8642	core					1		
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core				1			
***Carex* sp.**	Cyperaceae	8689	seed							
Carex sp. (mineralized)	Cyperaceae	8689	fragment							
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed		3	1		3		1
Gramineae SMALL	Gramineae	8856	fragment				3			
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed		1			1		
Gramineae MEDIUM	Gramineae	8856	fragment					1		
Gramineae LARGE >1.5mm	Gramineae	8856	fragment							
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment				1			
Compositae Kernels	Compositae	9947	Kernel	5	0	5	127	32		
Compositae Kernels	Compositae	9947	fragment	2	3	4		23		
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed		9	7	1	3		
Unidentifiable (indet.) seed fragment	N/A		fragment	3	17	29	82	18	2	14
Unidentifiable (indet.) seed core	N/A		core				10	4	1	
Small seed core type	N/A		core				8			
Unidentifiable (indet.) Non wood frag	N/A		fragment	5	3	77	50	33	4	
cf. Fruit flesh	N/A		fragment				1	2		
Reticulate 'Hook' fragments	N/A		fragment			13	1			
Burned masses (small)	N/A		1,2 or 5ml			1	2			1
Dung like pellet	N/A		pellet				1			
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment			2	10			
mineralized fruit/nut shell (mineralized)	N/A		fragment							
vitrified spike/fruit?	N/A		fragment							

Kharaneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AQ42	AR37	AR38	AR39	AR40	AR42	AR42
			Locus	004	035	008	003	008	004	008
			Description	Loose grey sediment	Light brown silty sediment -Locus containing (38)-(42) Dark Spots, beside hearth	Compact light brown sediment	Dark brown soil with lots of charcoal	Compact light brown sediment	Loose grey sediment	Compact light brown sediment (grape contamination)
			Stratigraphic Zone	1A	1A	2A	1A	2A	1A	2A
			Volume (l)	14.5	124	15.25	?	58	?	42
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment							
***Lepidium* sp. (fat type)**	Cruciferae	390	seed							
Cruciferae frag. (large)	Cruciferae	390	fragment							
Cruciferae sp.	Cruciferae	390	seed	2						
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed							
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed		8			10	4	14
Chenopodiaceae	Chenopodiaceae	1621	fragment					3		
***Atriplex* sp.**	Chenopodiaceae	1654	seed	4						
***Salsola* sp.**	Chenopodiaceae	1703	seed							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed							
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment							
cf. Leguminosae (large)	Leguminoseae	2161	seed							
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed		1					
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed		2					
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment		3					
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed							
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment							
cf. Cyperaceae core Type 1	Cyperaceae	8642	core	2				1		
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core							
***Carex* sp.**	Cyperaceae	8689	seed	1				2		
Carex sp. (mineralized)	Cyperaceae	8689	fragment							
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed					1		
Gramineae SMALL	Gramineae	8856	fragment							
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed							
Gramineae MEDIUM	Gramineae	8856	fragment							
Gramineae LARGE >1.5mm	Gramineae	8856	fragment							
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment							
Compositae Kernels	Compositae	9947	Kernel	4	2					
Compositae Kernels	Compositae	9947	fragment							
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed		1			5		
Unidentifiable (indet.) seed fragment	N/A		fragment	19	3			5	3	12
Unidentifiable (indet.) seed core	N/A		core	3						
Small seed core type	N/A		core					1		
Unidentifiable (indet.) Non wood frag	N/A		fragment	25	12		3	29	4	
cf. Fruit flesh	N/A		fragment							
Reticulate 'Hook' fragments	N/A		fragment	15				1		
Burned masses (small)	N/A		1,2 or 5ml	1						1
Dung like pellet	N/A		pellet							
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment	6						
mineralized fruit/nut shell (mineralized)	N/A		fragment							
vitrified spike/fruit?	N/A		fragment							

Kharaneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AS37	AS37	AS37	AS37	AS38	AS38	AS38
			Locus	003	008	034	035	003	004	008
			Description	Dark brown soil with lots of charcoal	Compact light brown sediment	Large grey ashy feature	Light brown silty sediment -Locus containing (38)-(42) Dark Spots, beside hearth	Dark brown soil with lots of charcoal	Loose grey sediment	Compact light brown sediment (bad wash)
			Stratigraphic Zone	1A	2A	1A	1A	1A	1A	2A
			Volume (l)	20	41	63	2	60	56	14
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed			1				
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment							
***Lepidium* sp. (fat type)**	Cruciferae	390	seed							
Cruciferae frag. (large)	Cruciferae	390	fragment							
Cruciferae sp.	Cruciferae	390	seed		1					
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed	2		1			1	
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	1	3	4		5	2	
Chenopodiaceae	Chenopodiaceae	1621	fragment	3						
***Atriplex* sp.**	Chenopodiaceae	1654	seed							
***Salsola* sp.**	Chenopodiaceae	1703	seed							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed							
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment	3				4		
cf. Leguminosae (large)	Leguminoseae	2161	seed							
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed							
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed						2	
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment							
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed							
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment							
cf. Cyperaceae core Type 1	Cyperaceae	8642	core							
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core							
***Carex* sp.**	Cyperaceae	8689	seed							
Carex sp. (mineralized)	Cyperaceae	8689	fragment					1	2	
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed		1				1	
Gramineae SMALL	Gramineae	8856	fragment							
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed							
Gramineae MEDIUM	Gramineae	8856	fragment							
Gramineae LARGE >1.5mm	Gramineae	8856	fragment	1						
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment							
Compositae Kernels	Compositae	9947	Kernel		2			1		
Compositae Kernels	Compositae	9947	fragment							
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed						4	
Unidentifiable (indet.) seed fragment	N/A		fragment	5				7		
Unidentifiable (indet.) seed core	N/A		core	1		1				
Small seed core type	N/A		core							
Unidentifiable (indet.) Non wood frag	N/A		fragment	19	9	17		26	6	3
cf. Fruit flesh	N/A		fragment							
Reticulate 'Hook' fragments	N/A		fragment	7						
Burned masses (small)	N/A		1,2 or 5ml	1						
Dung like pellet	N/A		pellet							
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment							
mineralized fruit/nut shell (mineralized)	N/A		fragment							
vitrified spike/fruit?	N/A		fragment							

Kharaneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AS38	AS39	AS39	AS39	AS40	AS41	AS41
			Locus	076	003	004	008	008	003	004
			Description	Compact Floor, beside hearth (067)	Dark brown soil with lots of charcoal	Loose grey sediment	Compact light brown sediment	Compact light brown sediment	Dark brown soil with lots of charcoal	Loose grey sediment
			Stratigraphic Zone	2A	1A	1A	2A	2A	1A	1A
			Volume (l)	?	?	50	25	33.75	?	75
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed							1
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment							
***Lepidium* sp. (fat type)**	Cruciferae	390	seed							
Cruciferae frag. (large)	Cruciferae	390	fragment							
Cruciferae sp.	Cruciferae	390	seed		1					
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed				2			
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed			2				2
Chenopodiaceae	Chenopodiaceae	1621	fragment							
***Atriplex* sp.**	Chenopodiaceae	1654	seed	5						
***Salsola* sp.**	Chenopodiaceae	1703	seed				1			
cf. *Salsola* sp.	Chenopodiaceae	1703	seed				2			
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment							
cf. Leguminosae (large)	Leguminoseae	2161	seed							
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed				2			
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed							
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment							
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed				1			
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment							
cf. Cyperaceae core Type 1	Cyperaceae	8642	core							
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core							
***Carex* sp.**	Cyperaceae	8689	seed							
Carex sp. (mineralized)	Cyperaceae	8689	fragment							
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed							
Gramineae SMALL	Gramineae	8856	fragment							
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed							
Gramineae MEDIUM	Gramineae	8856	fragment							
Gramineae LARGE >1.5mm	Gramineae	8856	fragment							
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment							
Compositae Kernels	Compositae	9947	Kernel			1				
Compositae Kernels	Compositae	9947	fragment		1					
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed				2			1
Unidentifiable (indet.) seed fragment	N/A		fragment		2	6	7			
Unidentifiable (indet.) seed core	N/A		core							
Small seed core type	N/A		core							
Unidentifiable (indet.) Non wood frag	N/A		fragment		5	2	15			14
cf. Fruit flesh	N/A		fragment							
Reticulate 'Hook' fragments	N/A		fragment				1			
Burned masses (small)	N/A		1,2 or 5ml							
Dung like pellet	N/A		pellet							
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment							
mineralized fruit/nut shell (mineralized)	N/A		fragment							
vitrified spike/fruit?	N/A		fragment							

Kharaneh IV Area A: Master Table			Area	A	A	A	A	A	A	A
			Square	AS41	AS41	AS42	AS42	AS42	AT37	AT37
			Locus	008	041	003	004	008	003	034
			Description	Compact light brown sediment	orange compact sediment	Dark brown soil with lots of charcoal	Loose grey sediment	Compact light brown sediment	Dark brown soil with lots of charcoal	Large grey ashy feature
			Stratigraphic Zone	2A	1A	1A	1A	2A	1A	1A
			Volume (l)	82	15	?	104	73	13	38
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**							
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed				3			
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment				2			
***Lepidium* sp. (fat type)**	Cruciferae	390	seed							
Cruciferae frag. (large)	Cruciferae	390	fragment							
Cruciferae sp.	Cruciferae	390	seed							
cf. Cruciferae	Cruciferae	390	seed							
***Capsella/Lepidium* type**	Cruciferae	516	seed					3		
cf. *Capparis*	Capparaceae	831	seed							
cf. *Polygonum* sp. core	Polygonaceae	1558	core							
Polygonum* cf. *salicifolium	Polygonaceae	1563	seed							
Chenopodiaceae spp.	Chenopodiaceae	1621	seed		3		13	9	2	2
Chenopodiaceae	Chenopodiaceae	1621	fragment					2		
***Atriplex* sp.**	Chenopodiaceae	1654	seed							
***Salsola* sp.**	Chenopodiaceae	1703	seed							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed							
Nitraria schoberi	Zygophyllaceae	2059	seed							
Nitraria schoberi	Zygophyllaceae	2059	fragment			3				
cf. Leguminosae (large)	Leguminoseae	2161	seed							
cf. Leguminosae (small)	Leguminoseae	2161	seed							
Lotus* cf. *corniculatus	Leguminosae	3179	seed							
***Anagalis* sp.**	Primulaceae	5451	seed							
cf. *Anagalis* sp.	Primulaceae	5451	seed							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed				1	1		
***Lithospermum* sp. Frag**	Boraginaceae	5688	fragment							
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed							
Cyperaceae spp.	Cyperaceae	8642	seed							
Cyperaceae spp.	Cyperaceae	8642	fragment							
cf. Cyperaceae core Type 1	Cyperaceae	8642	core							
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core							
***Carex* sp.**	Cyperaceae	8689	seed							
Carex sp. (mineralized)	Cyperaceae	8689	fragment							
Carex* cf. *divisia	Cyperaceae	8717	seed							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed							
Gramineae SMALL <1mm	Gramineae	8856	seed					1		
Gramineae SMALL	Gramineae	8856	fragment							
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed							
Gramineae MEDIUM	Gramineae	8856	fragment							
Gramineae LARGE >1.5mm	Gramineae	8856	fragment							
cf. Taeniatherum sp.	Gramineae	9536	fragment							
***Hordeum* sp.**	Gramineae	9280	fragment							
Compositae Kernels	Compositae	9947	Kernel			2				
Compositae Kernels	Compositae	9947	fragment							
Small cf. stick fragment	N/A		fragment							
Folded clump/root knot	N/A		fragment							
Unidentifiable (indet.) seed	N/A		seed				5		2	
Unidentifiable (indet.) seed fragment	N/A		fragment			2	3		2	3
Unidentifiable (indet.) seed core	N/A		core					3		
Small seed core type	N/A		core							
Unidentifiable (indet.) Non wood frag	N/A		fragment			8	16	25	5	2
cf. Fruit flesh	N/A		fragment							
Reticulate 'Hook' fragments	N/A		fragment							
Burned masses (small)	N/A		1,2 or 5ml							
Dung like pellet	N/A		pellet							
Tuber like fragment	N/A		1ml							
Tissue with Rugose surface	N/A		fragments							
Clump of cf. seeds/spores	N/A		fragment							
fruit/nut shell fragment	N/A		fragment							
mineralized fruit/nut shell (mineralized)	N/A		fragment				4			
vitrified spike/fruit?	N/A		fragment							

13.2. Master Data Table for Area A. Additional columns are shown on subsequent pages

Kharaneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	60.P1	60.P1	60.P1	60.P1	60.P1	60.P3	60.P3	60.P3
			Locus	027	028	030	031	032	002	004	005
			Description	Clayey deposit	Deposit	Deposit Alternating occupation surfaces and refuse. Midden?	Deposit	Deposit Alternating occupation surfaces and refuse. Midden?	Dark-brown rich organic sediment	mid grey sediment	Occupation surface
			Stratigraphic Zone	2B	2B	3B	3B	3B	1B	2B	2B
			Volume (l)	82	39.45	21.4	57	45.4	1	135	1
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed	3	2					13	
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment		1						
***Lepidium* sp. (fat type)**	Cruciferae	390	seed								
Cruciferae frag. (large)	Cruciferae	390	fragment								
Cruciferae sp.	Cruciferae	390	seed								
cf. Cruciferae	Cruciferae	390	seed								
***Capsella/Lepidium* type**	Cruciferae	516	seed		1	1		1	1		
cf. *Capparis*	Capperaceae	831	seed								
cf. *Polygonum* sp. core	Polygonaceae	1558	core							1	
Polygonum cf. salicifolium	Polygonaceae	1563	seed		1					1	
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	13	18	1	4	11		12	3
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed	3	6	1	2		16	23	
***Salsola* sp.**	Chenopodiaceae	1703	seed								
cf. *Salsola* sp.	Chenopodiaceae	1703	seed								
Nitraria schoberi	Zygophyllaceae	2059	seed			1	1			1	1
Nitraria schoberi	Zygophyllaceae	2059	fragment		15	4	2	9		1	
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed							1	
Lotus* cf. *corniculatus	Leguminosae	3179	seed		1						
***Anagalis* sp.**	Primulaceae	5451	seed	2							
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed	1							
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment								
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed								
Cyperaceae spp.	Cyperaceae	8642	seed							1	
Cyperaceae spp.	Cyperaceae	8642	fragment				1				
cf. Cyperaceae core Type 1	Cyperaceae	8642	core	2	1			4		4	
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core		1						
***Carex* sp.**	Cyperaceae	8689	seed								
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed	1							
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed	1							
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed								
Gramineae SMALL <1mm	Gramineae	8856	seed	2					3	1	
Gramineae SMALL	Gramineae	8856	fragment								
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								
Gramineae MEDIUM	Gramineae	8856	fragment	3					3		
Gramineae LARGE >1.5mm	Gramineae	8856	fragment			1			1	2	
cf. *Taeniatherum* sp.	Gramineae	9536	fragment							1	
***Hordeum* sp.**	Gramineae	9280	fragment		8	1				3	
Compositae Kernels	Compositae	9947	Kernel	1			1		2	2	
Compositae Kernels	Compositae	9947	fragment		1		1		2	4	
Small cf. stick fragment	N/A		fragment			6					
Folded clump/root knot	N/A		fragment								
Unidentifiable (indet.) seed	N/A		seed	2	1			1	8	3	1
Unidentifiable (indet.) seed fragment	N/A		fragment	11	15			2	6	26	3
Unidentifiable (indet.) seed core	N/A		seed core	1	1				4		
Small seed core type	N/A		seed core		1					1	
Unidentifiable (indet.) Non wood frag	N/A		fragment	13	16			35	13	102	8
cf. Fruit flesh	N/A		fragment		1		2				1
Reticulate 'Hook' fragments	N/A		fragment		1						
Burned masses (small)	N/A		1,2 or 5 ml of frags	2	2		1			1	
Dung like pellet	N/A		pellet								
Tuber like fragment	N/A		<1ml of frags			1				1	
Tissue with Rugose surface	N/A		fragments								
Clump of cf. seeds/spores	N/A		fragment								
fruit/nut shell fragment	N/A		fragment	3	4						
mineralized fruit/nut shell (mineralized)	N/A		fragment								
vitrified spike/fruit?	N/A		fragment								

Kharaneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3
			Locus	006	009	027	034	061	090	091	099
			Description	Deposit	Deposit	Clayey deposit	Deposit	Deposit	Light grey silty clay deposit	mid brown clayey silt	Whiteish sediment
			Stratigraphic Zone	2B	2B	2B		2B	2B	2B	2B
			Volume (l)	3.5	10	95	9	32	12	49	2
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed			1	1				
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment						3		
***Lepidium* sp. (fat type)**	Cruciferae	390	seed								
Cruciferae frag. (large)	Cruciferae	390	fragment			1			2		
Cruciferae sp.	Cruciferae	390	seed								
cf. Cruciferae	Cruciferae	390	seed								
***Capsella/Lepidium* type**	Cruciferae	516	seed				1	1			
cf. *Capparis*	Capperaceae	831	seed								
cf. *Polygonum* sp. core	Polygonaceae	1558	core								
Polygonum cf. salicifolium	Polygonaceae	1563	seed								
Chenopodiaceae spp.	Chenopodiaceae	1621	seed		1		4	18	2		
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed		1	8	2	2			
***Salsola* sp.**	Chenopodiaceae	1703	seed			2					
cf. *Salsola* sp.	Chenopodiaceae	1703	seed								
Nitraria schoberi	Zygophyllaceae	2059	seed			2					
Nitraria schoberi	Zygophyllaceae	2059	fragment			23					
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed								
Lotus* cf. *corniculatus	Leguminosae	3179	seed								
***Anagalis* sp.**	Primulaceae	5451	seed								
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment								
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed			2					
Cyperaceae spp.	Cyperaceae	8642	seed		1						
Cyperaceae spp.	Cyperaceae	8642	fragment								
cf. Cyperaceae core Type 1	Cyperaceae	8642	core			1					
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core								
***Carex* sp.**	Cyperaceae	8689	seed		1						
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed								
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed								
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed								
Gramineae SMALL <1mm	Gramineae	8856	seed			1	1				
Gramineae SMALL	Gramineae	8856	fragment			3					
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								
Gramineae MEDIUM	Gramineae	8856	fragment								
Gramineae LARGE >1.5mm	Gramineae	8856	fragment					2			
cf. *Taeniatherum* sp.	Gramineae	9536	fragment								
***Hordeum* sp.**	Gramineae	9280	fragment								
Compositae Kernels	Compositae	9947	Kernel	1							
Compositae Kernels	Compositae	9947	fragment								
Small cf. stick fragment	N/A		fragment		1		1				
Folded clump/root knot	N/A		fragment								
Unidentifiable (indet.) seed	N/A		seed				3				
Unidentifiable (indet.) seed fragment	N/A		fragment			1	4	9	2		
Unidentifiable (indet.) seed core	N/A		seed core					1			
Small seed core type	N/A		seed core				1				
Unidentifiable (indet.) Non wood frag	N/A		fragment	3	15	4		7	9	24	
cf. Fruit flesh	N/A		fragment					1			
Reticulate 'Hook' fragments	N/A		fragment			1					
Burned masses (small)	N/A		1,2 or 5 ml of frags								
Dung like pellet	N/A		pellet								
Tuber like fragment	N/A		<1ml of frags								
Tissue with Rugose surface	N/A		fragments								
Clump of cf. seeds/spores	N/A		fragment			1					
fruit/nut shell fragment	N/A		fragment					1			
mineralized fruit/nut shell (mineralized)	N/A		fragment								
vitrified spike/fruit?	N/A		fragment								

Khareneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3	60.P3
			Locus	27	104	108	110	115	124	128	139
			Description	Desiment/ Deposit - mid brown	Dark brown deposit	Burnt area	light grey deposit	light brown bone concentration	occupation surface/ compact with white clay	loose bone layer in orange clay	Ashy charcoal and bone concentration (pit fill in 061)
			Stratigraphic Zone			2B	2B	2B	2B	2B	2B
			Volume (l)	82	22	6	10	11	38	10	2
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment								
***Lepidium* sp. (fat type)**	Cruciferae	390	seed								
Cruciferae frag. (large)	Cruciferae	390	fragment								
Cruciferae sp.	Cruciferae	390	seed								
cf. Cruciferae	Cruciferae	390	seed								
***Capsella/Lepidium* type**	Cruciferae	516	seed	1							
cf. *Capparis*	Capperaceae	831	seed								
cf. *Polygonum* sp. core	Polygonaceae	1558	core								
Polygonum cf. salicifolium	Polygonaceae	1563	seed								
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	18	1		1				
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed	6	1	9					
***Salsola* sp.**	Chenopodiaceae	1703	seed	2							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed							1	
Nitraria schoberi	Zygophyllaceae	2059	seed	1							
Nitraria schoberi	Zygophyllaceae	2059	fragment	9		10					
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed								
Lotus* cf. *corniculatus	Leguminosae	3179	seed								
***Anagalis* sp.**	Primulaceae	5451	seed								
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment								
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed								
Cyperaceae spp.	Cyperaceae	8642	seed								
Cyperaceae spp.	Cyperaceae	8642	fragment								
cf. Cyperaceae core Type 1	Cyperaceae	8642	core	1							
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core								
***Carex* sp.**	Cyperaceae	8689	seed								
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed								
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed								
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed	3							
Gramineae SMALL <1mm	Gramineae	8856	seed	1						1	
Gramineae SMALL	Gramineae	8856	fragment								
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								
Gramineae MEDIUM	Gramineae	8856	fragment			1					
Gramineae LARGE >1.5mm	Gramineae	8856	fragment								
cf. *Taeniatherum* sp.	Gramineae	9536	fragment								
***Hordeum* sp.**	Gramineae	9280	fragment								
Compositae Kernels	Compositae	9947	Kernel			10	1	1			
Compositae Kernels	Compositae	9947	fragment	1							
Small cf. stick fragment	N/A		fragment								
Folded clump/root knot	N/A		fragment	1							
Unidentifiable (indet.) seed	N/A		seed							3	
Unidentifiable (indet.) seed fragment	N/A		fragment	13	6	1				1	
Unidentifiable (indet.) seed core	N/A		seed core								
Small seed core type	N/A		seed core								
Unidentifiable (indet.) Non wood frag	N/A		fragment	68	18	1		2	6	7	
cf. Fruit flesh	N/A		fragment								
Reticulate 'Hook' fragments	N/A		fragment								
Burned masses (small)	N/A		1,2 or 5 ml of frags	1		1					
Dung like pellet	N/A		pellet								
Tuber like fragment	N/A		<1ml of frags								
Tissue with Rugose surface	N/A		fragments								
Clump of cf. seeds/spores	N/A		fragment								
fruit/nut shell fragment	N/A		fragment	2		4					
mineralized fruit/nut shell (mineralized)	N/A		fragment								
vitrified spike/fruit?	N/A		fragment	2							

Khareneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	60.P3	60.P3	60.P3	AV72	AV73	AV73	AV73	AV73
			Locus	140	151	156	073	074	086	137	141
			Description	Bone layer "big"	grey loose ashy deposit	sterile clay	light grey silt deposit	mid grey deposit	mid brown deposit	Dark deposit	loose sandy silt deposit
			Stratigraphic Zone	2B	2B	2B	2B	2B	2B		2B
			Volume (l)	22	16	13	31	27	0.3	12	27
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment								
***Lepidium* sp. (fat type)**	Cruciferae	390	seed								
Cruciferae frag. (large)	Cruciferae	390	fragment								
Cruciferae sp.	Cruciferae	390	seed		1						
cf. Cruciferae	Cruciferae	390	seed								
***Capsella/Lepidium* type**	Cruciferae	516	seed								5
cf. *Capparis*	Capperaceae	831	seed								
cf. *Polygonum* sp. core	Polygonaceae	1558	core								
Polygonum cf. salicifolium	Polygonaceae	1563	seed								
Chenopodiaceae spp.	Chenopodiaceae	1621	seed		2	1					17
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed		2		1				149
***Salsola* sp.**	Chenopodiaceae	1703	seed								
cf. *Salsola* sp.	Chenopodiaceae	1703	seed								
Nitraria schoberi	Zygophyllaceae	2059	seed								
Nitraria schoberi	Zygophyllaceae	2059	fragment								11
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed								
Lotus* cf. *corniculatus	Leguminosae	3179	seed								
***Anagalis* sp.**	Primulaceae	5451	seed								7
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed				7	4			
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment					1			
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed								
Cyperaceae spp.	Cyperaceae	8642	seed								2
Cyperaceae spp.	Cyperaceae	8642	fragment								
cf. Cyperaceae core Type 1	Cyperaceae	8642	core			1					
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core								2
***Carex* sp.**	Cyperaceae	8689	seed								
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed		1						
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed								
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed								
Gramineae SMALL <1mm	Gramineae	8856	seed		1		1				4
Gramineae SMALL	Gramineae	8856	fragment								
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								1
Gramineae MEDIUM	Gramineae	8856	fragment								
Gramineae LARGE >1.5mm	Gramineae	8856	fragment								
cf. *Taeniatherum* sp.	Gramineae	9536	fragment								
***Hordeum* sp.**	Gramineae	9280	fragment								
Compositae Kernels	Compositae	9947	Kernel							2	2
Compositae Kernels	Compositae	9947	fragment								1
Small cf. stick fragment	N/A		fragment								
Folded clump/root knot	N/A		fragment								
Unidentifiable (indet.) seed	N/A		seed								1
Unidentifiable (indet.) seed fragment	N/A		fragment				2	4		2	31
Unidentifiable (indet.) seed core	N/A		seed core								3
Small seed core type	N/A		seed core								
Unidentifiable (indet.) Non wood frag	N/A		fragment		25	2		2	1		31
cf. Fruit flesh	N/A		fragment		1						
Reticulate 'Hook' fragments	N/A		fragment								1
Burned masses (small)	N/A		1,2 or 5 ml of frags				5				1
Dung like pellet	N/A		pellet								
Tuber like fragment	N/A		<1ml of frags								1
Tissue with Rugose surface	N/A		fragments								
Clump of cf. seeds/spores	N/A		fragment								
fruit/nut shell fragment	N/A		fragment								1
mineralized fruit/nut shell (mineralized)	N/A		fragment								
vitrified spike/fruit?	N/A		fragment								

Kharaneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	AV74	AV74	AV74	AW72	AW72	AW72	AW72	AW73
			Locus	088	127	141	073	074	087	149	002
			Description	Bone layer	soft loose bone layer	loose sandy silt deposit	light grey silt deposti	mid grey deposit	compact deposit with burnth lithics	loose sandy deposit	Dark brown rich organic sediment
			Stratigraphic Zone			2B	2B	2B	2B	2B	1B
			Volume (l)	22	20	60	30	67	23	15	127
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed			1					
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment								
***Lepidium* sp. (fat type)**	Cruciferae	390	seed								
Cruciferae frag. (large)	Cruciferae	390	fragment								
Cruciferae sp.	Cruciferae	390	seed			1					
cf. Cruciferae	Cruciferae	390	seed			1					
***Capsella/Lepidium* type**	Cruciferae	516	seed			1					
cf. *Capparis*	Capperaceae	831	seed								
cf. *Polygonum* sp. core	Polygonaceae	1558	core								
Polygonum cf. salicifolium	Polygonaceae	1563	seed								
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	2	3	19		3	2		
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed	1	8	29		1	4		53
***Salsola* sp.**	Chenopodiaceae	1703	seed								
cf. *Salsola* sp.	Chenopodiaceae	1703	seed								
Nitraria schoberi	Zygophyllaceae	2059	seed					1			
Nitraria schoberi	Zygophyllaceae	2059	fragment			8					6
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed								
Lotus* cf. *corniculatus	Leguminosae	3179	seed								
***Anagalis* sp.**	Primulaceae	5451	seed								
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed	5	5	5	12	73	16	11	1
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment					9	1	1	
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed								
Cyperaceae spp.	Cyperaceae	8642	seed					1			
Cyperaceae spp.	Cyperaceae	8642	fragment		1						
cf. Cyperaceae core Type 1	Cyperaceae	8642	core								
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core			1					
***Carex* sp.**	Cyperaceae	8689	seed					1			
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed			1					
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed		1	2					1
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed								
Gramineae SMALL <1mm	Gramineae	8856	seed			1			1		2
Gramineae SMALL	Gramineae	8856	fragment								
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								
Gramineae MEDIUM	Gramineae	8856	fragment			1					
Gramineae LARGE >1.5mm	Gramineae	8856	fragment								
cf. *Taeniatherum* sp.	Gramineae	9536	fragment								
***Hordeum* sp.**	Gramineae	9280	fragment								
Compositae Kernels	Compositae	9947	Kernel			6			1		5
Compositae Kernels	Compositae	9947	fragment	1	3	2		1	3		
Small cf. stick fragment	N/A		fragment								
Folded clump/root knot	N/A		fragment								
Unidentifiable (indet.) seed	N/A		seed			1		1			
Unidentifiable (indet.) seed fragment	N/A		fragment	6	7	14		3			7
Unidentifiable (indet.) seed core	N/A		seed core								
Small seed core type	N/A		seed core								1
Unidentifiable (indet.) Non wood frag	N/A		fragment	4	10	21	3	16		5	
cf. Fruit flesh	N/A		fragment								
Reticulate 'Hook' fragments	N/A		fragment								
Burned masses (small)	N/A		1,2 or 5 ml of frags			1	1				
Dung like pellet	N/A		pellet								
Tuber like fragment	N/A		<1ml of frags								
Tissue with Rugose surface	N/A		fragments								
Clump of cf. seeds/spores	N/A		fragment								
fruit/nut shell fragment	N/A		fragment								
mineralized fruit/nut shell (mineralized)	N/A		fragment	1							
vitrified spike/fruit?	N/A		fragment								

Khraneh IV Area A: Master Table			Area	B	B	B	B	B	B	B	B
			Square	AW73	AW73	AW73	AW73	AW73	AW74	AY72	AY72
			Locus	081	082	086	087	130	086	040	041
			Description	Very dark brown deposit/fill	Very dark brown to black hearth fill	Mid brown deposit	Compact deposit with burnt lithics	Loose brown deposit beneath lithics scatter (95)	mid brown deposit	Occupation Surface	Deposit
			Stratigraphic Zone	2B		2B			2B	1B	1B
			Volume (l)	17	2.5	27	37	7	0.3	22	11
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed								
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment								
***Lepidium* sp. (fat type)**	Cruciferae	390	seed	2							
Cruciferae frag. (large)	Cruciferae	390	fragment								
Cruciferae sp.	Cruciferae	390	seed								
cf. Cruciferae	Cruciferae	390	seed								
***Capsella/Lepidium* type**	Cruciferae	516	seed	2							
cf. *Capparis*	Capperaceae	831	seed	1							
cf. *Polygonum* sp. core	Polygonaceae	1558	core								
Polygonum cf. salicifolium	Polygonaceae	1563	seed								
Chenopodiaceae spp.	Chenopodiaceae	1621	seed			8	9		1	2	
Chenopodiaceae	Chenopodiaceae	1621	fragment								
***Atriplex* sp.**	Chenopodiaceae	1654	seed	64			31				
***Salsola* sp.**	Chenopodiaceae	1703	seed	12							
cf. *Salsola* sp.	Chenopodiaceae	1703	seed								
Nitraria schoberi	Zygophyllaceae	2059	seed								
Nitraria schoberi	Zygophyllaceae	2059	fragment	2			4				
cf. Leguminosae (large)	Leguminoseae	2161	seed								
cf. Leguminosae (small)	Leguminoseae	2161	seed								
Lotus* cf. *corniculatus	Leguminosae	3179	seed								
***Anagalis* sp.**	Primulaceae	5451	seed	1							
cf. *Anagalis* sp.	Primulaceae	5451	seed								
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed	3							2
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment								
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed								
Cyperaceae spp.	Cyperaceae	8642	seed								
Cyperaceae spp.	Cyperaceae	8642	fragment								
cf. Cyperaceae core Type 1	Cyperaceae	8642	core								
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core								
***Carex* sp.**	Cyperaceae	8689	seed								
Carex sp. (mineralized)	Cyperaceae	8689	fragment								
Carex* cf. *divisia	Cyperaceae	8717	seed							1	
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed								
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed								
Gramineae SMALL <1mm	Gramineae	8856	seed								
Gramineae SMALL	Gramineae	8856	fragment								
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed								
Gramineae MEDIUM	Gramineae	8856	fragment								
Gramineae LARGE >1.5mm	Gramineae	8856	fragment								
cf. *Taeniatherum* sp.	Gramineae	9536	fragment								
***Hordeum* sp.**	Gramineae	9280	fragment								
Compositae Kernels	Compositae	9947	Kernel	9							
Compositae Kernels	Compositae	9947	fragment	13			5			2	
Small cf. stick fragment	N/A		fragment								
Folded clump/root knot	N/A		fragment								
Unidentifiable (indet.) seed	N/A		seed			1			1		
Unidentifiable (indet.) seed fragment	N/A		fragment	12	1	1	5			14	2
Unidentifiable (indet.) seed core	N/A		seed core								
Small seed core type	N/A		seed core								
Unidentifiable (indet.) Non wood frag	N/A		fragment			10	11			10	3
cf. Fruit flesh	N/A		fragment								
Reticulate 'Hook' fragments	N/A		fragment								
Burned masses (small)	N/A		1,2 or 5 ml of frags	5							
Dung like pellet	N/A		pellet	2							
Tuber like fragment	N/A		<1ml of frags								
Tissue with Rugose surface	N/A		fragments	3							
Clump of cf. seeds/spores	N/A		fragment								
fruit/nut shell fragment	N/A		fragment								
mineralized fruit/nut shell (mineralized)	N/A		fragment								
vitrified spike/fruit?	N/A		fragment								

Khareneh IV Area A: Master Table			Area	B	B	B	B	B	B
			Square	AY72	AY73	AY74	AZ72	AZ72	AZ72
			Locus	114	041	041	002	036	040
			Description	Dark deposit	Deposit	Deposit	Dark brown rich organic sediment	Deposit	Deposit
			Stratigraphic Zone		1B	1B	1B	1B	1B
			Volume (l)	46	31	1	71	27	77
Taxon	**Family (FoT)**	**FoT number**	**Plant Part**						
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	seed						
***Sinapis/Brassica tournefortii* type**	Cruciferae	358	fragment						
***Lepidium* sp. (fat type)**	Cruciferae	390	seed						
Cruciferae frag. (large)	Cruciferae	390	fragment						
Cruciferae sp.	Cruciferae	390	seed						
cf. Cruciferae	Cruciferae	390	seed	2			1		
***Capsella/Lepidium* type**	Cruciferae	516	seed						1
cf. *Capparis*	Capperaceae	831	seed						
cf. *Polygonum* sp. core	Polygonaceae	1558	core						
Polygonum cf. salicifolium	Polygonaceae	1563	seed						
Chenopodiaceae spp.	Chenopodiaceae	1621	seed	4	5		7	4	6
Chenopodiaceae	Chenopodiaceae	1621	fragment						
***Atriplex* sp.**	Chenopodiaceae	1654	seed	13			1		2
***Salsola* sp.**	Chenopodiaceae	1703	seed	9					
cf. *Salsola* sp.	Chenopodiaceae	1703	seed						
Nitraria schoberi	Zygophyllaceae	2059	seed						
Nitraria schoberi	Zygophyllaceae	2059	fragment						
cf. Leguminosae (large)	Leguminoseae	2161	seed						
cf. Leguminosae (small)	Leguminoseae	2161	seed						
Lotus* cf. *corniculatus	Leguminosae	3179	seed						
***Anagalis* sp.**	Primulaceae	5451	seed				1		1
cf. *Anagalis* sp.	Primulaceae	5451	seed	1			1		
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	seed	1			1	6	1
***Lithospermum* sp. (mineralized)**	Boraginaceae	5688	fragment				1	4	2
cf. *Labiatae/Eragrostis* Type	Labiatae/Gramineae	6548	seed						
Cyperaceae spp.	Cyperaceae	8642	seed						
Cyperaceae spp.	Cyperaceae	8642	fragment						
cf. Cyperaceae core Type 1	Cyperaceae	8642	core						
cf. Cyperaceae core Type 2 (long)	Cyperaceae	8642	core						
***Carex* sp.**	Cyperaceae	8689	seed				1		
Carex sp. (mineralized)	Cyperaceae	8689	fragment						
Carex* cf. *divisia	Cyperaceae	8717	seed				1		
***Carex* cf. *hispidia* Type**	Cyperaceae	8744	seed						
cf. Gramineae (Pooadiae Type)	Gramineae	8856	seed						
Gramineae SMALL <1mm	Gramineae	8856	seed				1	1	
Gramineae SMALL	Gramineae	8856	fragment						
Gramineae MEDIUM 1-1.5mm	Gramineae	8856	seed						
Gramineae MEDIUM	Gramineae	8856	fragment						
Gramineae LARGE >1.5mm	Gramineae	8856	fragment						
cf. *Taeniatherum* sp.	Gramineae	9536	fragment						
***Hordeum* sp.**	Gramineae	9280	fragment						
Compositae Kernels	Compositae	9947	Kernel	1		1			2
Compositae Kernels	Compositae	9947	fragment	2			1		
Small cf. stick fragment	N/A		fragment						
Folded clump/root knot	N/A		fragment						
Unidentifiable (indet.) seed	N/A		seed	5					
Unidentifiable (indet.) seed fragment	N/A		fragment	28		2	11	8	15
Unidentifiable (indet.) seed core	N/A		seed core					4	
Small seed core type	N/A		seed core				1		
Unidentifiable (indet.) Non wood frag	N/A		fragment	3	11	6	14		4
cf. Fruit flesh	N/A		fragment						
Reticulate 'Hook' fragments	N/A		fragment						
Burned masses (small)	N/A		1,2 or 5 ml of frags	1					
Dung like pellet	N/A		pellet						
Tuber like fragment	N/A		<1ml of frags						
Tissue with Rugose surface	N/A		fragments						
Clump of cf. seeds/spores	N/A		fragment						
fruit/nut shell fragment	N/A		fragment						
mineralized fruit/nut shell (mineralized)	N/A		fragment						
vitrified spike/fruit?	N/A		fragment						

Appendix 3: Kharaneh IV Archaeobotanical Seed Catalogue

Introduction

This section consists of the seed catalogue for Kharaneh IV. Here I provide a concise description of the major taxa encountered at the site, which serves as a guide to the reference collection I have created for Kharaneh IV. For abundance of each individual taxon see the Master Data Tables included in Appendix 2. Measurements reflect the average dimensions of the total seeds present at the site. If there was variation in size, the range of sizes are listed, see also the scale bar in each image for reference. For further information on the identification, photography and methodology see Chapter 5. The taxa included in this catalogue are presented in the order of the *Flora of Turkey*.

Abbreviations used: *Flora Palestinia* (FP), *Flora of Turkey* (FoT), Length (L), Breadth (B), Thickness (Th), UoN (University of Nottingham), UCL (University College London-Near Eastern Reference collection and the Hillman Abu-Huyera Reference material), BIU (Bar Illan University, Israel).

Taxon list

Sinapis/Brassica tournefortii type
Lepidium sp. (fat type)
Capsella/Lepidium type
Cruciferae sp.
cf. *Capparis*
Polygonum cf. *salicifolium*
Chenopodiaceae spp.
Atriplex sp.
Salsola sp.
Nitraria schoberi
cf. Leguminosae (large)
cf. Leguminosae (small)
Lotus cf. *corniculatus*
Anagalis sp.
Lithospermum sp. (mineralized)
cf. *Labiatae/Eragrostis* Type
Cyperaceae sp.
cf. Cyperaceae core Type 1
cf. Cyperaceae core Type 2 (long)
Carex sp. (mineralized)
Carex cf. *divisia*
Carex cf. *hispidia* Type
cf. Gramineae (Pooadiae Type)
cf. *Taeniatherum sp.*
Hordeum spp.
Gramineae LARGE >1.5mm
Gramineae MEDIUM 1-1.5mm
Gramineae MEDIUM
Gramineae SMALL <1mm
Gramineae SMALL
cf. Compositae Kernel
Small Seed Core Type
Reticulate 'hook' fragments
cf. Fruit flesh

Taxon Descriptions

Taxon: ***Sinapis/Brassica tournefortii* Type**

Family: Cruciferae

Common Name/ Arabic or Local: Name: Mustard/ *qarras; shiltam*

Measurements: L:1.25mm, B:0.9mm, Th:0.9mm

Description: Overall these seeds have an ovate/globus shape with a slight "pinch" or gathering at the embryo end. There is a subtle ridge that runs along one side. The surface texture is colliculate and the cells appear to run in rows. Van Zeist et al. (1987) suggested that *Sinapis* sp. has a fainter reticulum than *Brassica*.

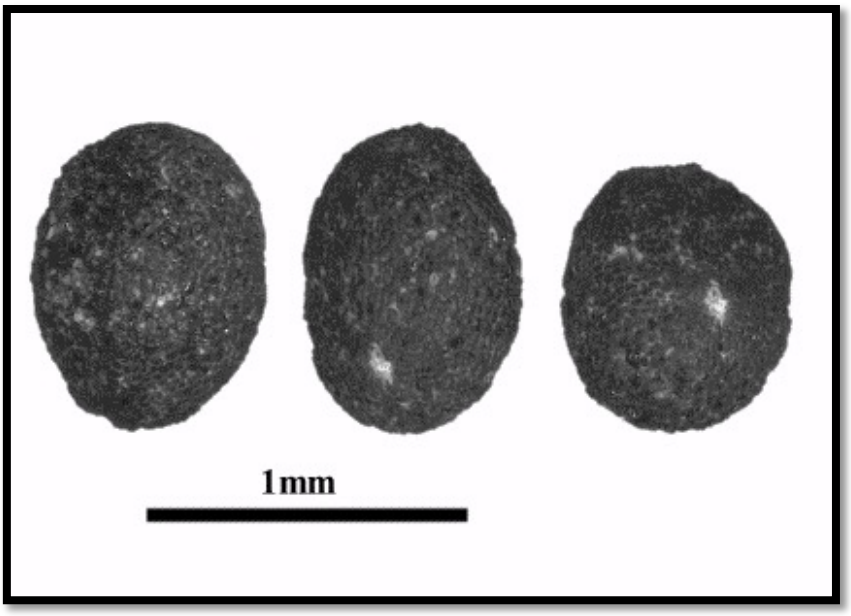
Regional/Temporally Similar Archaeological Occurrences: *B. tournefortii* is present in Nelson's (1973) Azraq Oasis Vegetation. Wilcox (2002) noted the deliberate collection and probable use as food of ground *Brassica/Sinapis* in the form of two "cakes" at Jerf el Ahmar. *Sinapis alba* is present in Jordan (Tukan *et al.* 1998).

Geographical Distribution: Turkey, W Europe, S Europe, N Africa, W Syria, Iran, Cyprus (FoT)

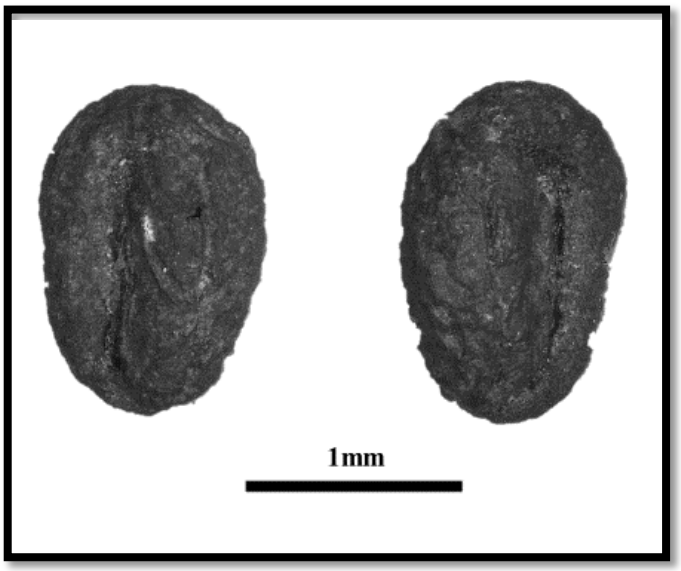
Habitat: Waste places (FoT), Native distribution in areas of wind blown, sandy arid, or semi-arid environments (Minnich and Sanders, 2000).

Reference Collections Consulted: UCL, BIU, UoN

Uses/Ethnographic Examples: Cruciferous taxa (*Brassica* and *Sinapis*) have provided oil, flavourings and leaves for millennia and are common archaeological finds (Zohary and Hopf 2000). Tukan *et al.* (1998) note the use of young stems and leaves from *Sinapis alba* in Jordan. Cultivated as an oil crop in Tibet and India (Hammer et al. 2013).



Taxon:	***Lepidium sp.* (fat type)**
Family:	Cruciferae
Common Name/ Arabic or Local: Name:	Peppercress, peppergrass, garden cress/ *Rashad* (Mandaville 2011)
Measurements:	L: 1.6mm, B: 1.1mm, Th: 0.6mm
Description:	Elliptical overall shape, There is a secondary groove visible but is very shallow. The end of the radical does not curve above the cotyledons and is as wide as the cotyledons and point upwards (similar to *Lepidium ruderale*). This is the largest Cruiciferae present at KHIV.
Regional/Temporally Similar Archaeological Occurrences:	Nelson (1973) lists two species of *Lepidium* in the Azraq Oasis (*L. aucheri* and *L. crassifolium (AKA: L. cartilagineum* in FoT*). L. aucheri* is not present in the FoT, but is presented in the FP, while *L. cartilagineum* is present in the FoT, but not the FP. Hillman notes the presence of three types of *Lepidium* (*L. perfoliatum, L. ruderal*, *L./Camelina/Camphorosma* types at Abu Huyera (Moore et al. 2000). *L. aucheri* is the only *Lepidium* listed and discussed in Al-Eisawi's survey of the Vegetation of Jordan (1996).
Geographical Distribution:	*L. ruderale:* Turkey Temperate Europe SW Asia, *L.aucheri*: Irano-Turanian phytogeograpical zone (FoT),
Habitat:	Wide ranging. *L. aucheri*: Deserts (Danin 2013); somewhat saline ground (FP), *L cartilagineum*: saline soils and salt rich plains. *L. stavium*: waste places, *L. ruderale:* roadsides and waste places (FoT). *L. latifolium,* also present in Jordan is a plant of wet places, especially coastal saline wetlands, but also non-saline stream-sides, marshes (Francis and Warwick, 2007).
Reference Collections Consulted:	UCL, BIU, UoN
Uses/Ethnographic Examples:	According to Hooper (1937) *Lepidium stavium* is used by Bedouins in Iraq and Iran as a tonic, aphrodisiac and diuretic. Tukan *et al*. (1998) also lists the leaves and young stems as a wild edible species in Jordan.



Taxon: ***Capsella/Lepidium* Type**

Family: Cruciferae

Common Name/ Arabic or Local: Name: *Capsella*: Shepherds purse/*Lepidium sativum:* Garden Cress, peppercress/ *rashād* (Hooper 1937, 136)

Measurements: L: 0.6-1.0mm, B: 0.5-0.8mm,Th: 0.2-0.3mm

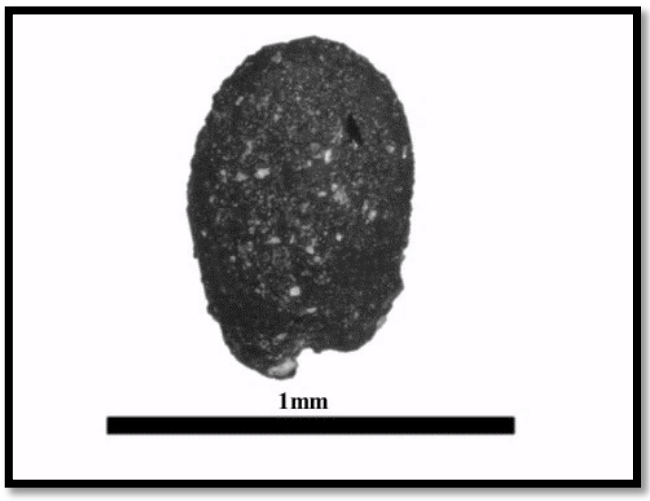
Description: These seeds are small and missing outer coats. The tip of the radicle curves beyond the cotyledons suggesting *Capsella* sp. However, it is very small and difficult to view the embryo/ventral side. Observations of specimens of *Lepidium ruderale* from the Hula Plain at BIU were very similar in shape and size. Sue Colledge suggested *Capsella* sp. or *Lepidium* and in comparison with the UCL collection, both of these seemed a likely possibility due to their overall elliptical shape and small size. These two genera have been confused as each other (e.g.: Krober-Grohne (1967). Here some appear to be slightly puffed, due to preservation however, the overall shape suggests these are the same species.

Regional/Temporally Similar Archaeological Occurrences: See description/discussion of *Lepidium* sp. *Capsella bursa-pastoris* is present at Abu Huyera (Hillman 2000). There are only two species of *Capsella* listed in the FoT (*C. bursa-pastoris* and *C. rubella,* which is listed as present in the Greek islands and prefers waste places, so likely not relevant here).

Habitat: For *Capsella bursa-pastoris*: cultivated land, waste places, disturbed habitats (Danin, 2013).

Reference Collections Consulted: UCL (Hillman Collection), BIU.

Uses/Ethnographic Examples: At Catalhoyuk, Fairbairn *et al*. (2007) suggested wild crucifer seeds, such as *Capsella,* were a deliberately targeted resource evidenced by bulk storage. Helbæk (1964, 122) discussed crucifers as an oil source, and Townsend and Guest (1980) suggested their use as flavouring. Today, the leaves are regularly gathered for salads in central Anatolia (Ertug-Yaras¸ 1997). The young leaves and stems of *Lepidium sativum* are also listed as an edible wild plant in Jordan by Tukan *et al*. (1998). Hopper (1973,136) notes the use of *L. sativum* as a tonic, aphrodisiac and diuretic.



Taxon: **Cruciferae sp.**

Family: Cruciferae

Common Name/ Arabic or Local: Name: Mustard/Cabbage family

Description: No Photo-This general identification was given to members of the Cruiciferae family where further identification was not possible. These seeds were all similar and dorso-ventrally compressed, obovoid in shape with a radicle tip extending beyond the body of the seed.

Habitat: The majority of species in Crucifereae family occupy arid habitats with minimal annual rainfall (Al-Shehbaz, 2011)

Taxon: **cf. *Capparis sp.***

Family: Caparaceae

Common Name/ Arabic or Local: Name: Caper / *Shafallah* (Mandaville 2011)

Measurements L: 1.2mm, B: 0.9mm,Th: 0.5mm

Description: The radicle lobe extends ¾ of the total seed length. The overall shape is mitaform and broadly oblong. Slightly smaller than G. Wilcox's online reference catalogue (accessed 2016) and in Rivera *et al.* (2002)'s discussion of identifying *Capparis* sp. Similar to images in M. Savard's PhD (viewed M.Nesbitt's copy), van Zeists drawings in Smith *et al.*'s (1974) report on Ganj Dareh Tepe, Iran, as well as van Zeist's (1984) drawings from Late-Palaeolithic Mureybit. Also compared with van Zeist and Bakker-Heeres (1982, 214).

Regional/Temporally Similar Archaeological Occurrences: *Capparis* spp. are present at Abu Huyera (Hillman in Moor *et al.* 2000), *Capparis spinosa* is the only species of *Capparis* listed by Nelson (1973) for the Azraq desert oasis. For other time periods see Rivera *et al*. (2002). Al-Esawi (1996) lists 6 species of *Capparis* in Azraq: *C. cartilaginea, C. decidua, C. leucophyla, C. ovato, C. pariflora C. spinosa*

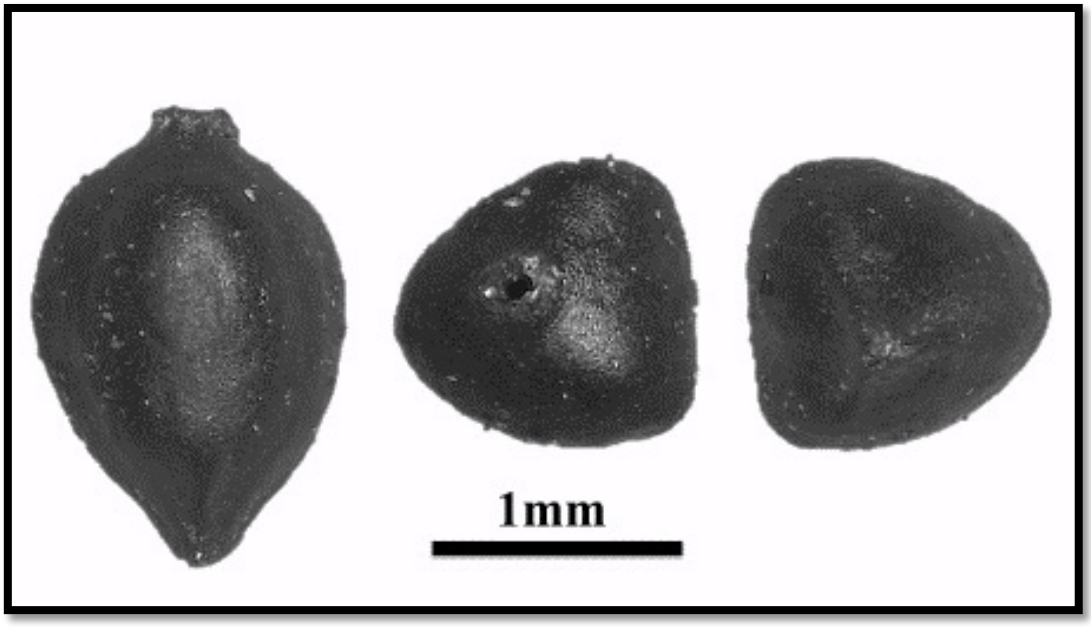
Habitat: Hard rock outcrops, disturbed habitats (Danin, 2013).

Reference Collections Consulted: UCL, BIU, UoN

Uses/Ethnographic Examples: *Capparis* spp. used for their fruit and edible flower buds (Taifour and El-Oqlah 2014). Flowers also used ornamentally (Al-Esawi 1996).



Taxon:	***Polygonum cf. salicifolium***
Family:	Polygonaceae
Common Name/ Arabic or Local: Name:	Knotweed, Sorrel
Measurements:	L: 1.9mm, B: 1.1mm, Th: 1.1mm
Description:	This seed/nutlet is nicely preserved. The seed is obovoid, and in cross section, very broadly triangular. The pinched ridges fade as they move away the apex. The attachment point is quite clearly on the ventral end of the seed and is prominent. The surface of the seed is favulariate. As we only have a single seed, the cf. classification is safer as it is also very reminiscent in overall shape and size of the *Scirpus* sp./*Bolboschoenus maritimus* recovered at Catalhoyuk (see: Wollstonecroft et al. 2008).
Regional/Temporally Similar Archaeological Occurrences:	At Ohalo II, Kislev (1992) recorded *Scirpus littoralis*. Nelson (1973) lists 7 Polygonaceae in the Azraq Oasis and the only *Polygonum* is *P. equisetiforme*.
Geographical Distribution:	Turkey, Mediterranean, Syrian desert, Arabia (FoT)
Habitat:	Wet Marshy lowlands , swamps near sea level (FoT)
Reference Collections Consulted:	UCL, The *Polygonum cf. salicifolium* identification was made after discussions with Yoel Melamed at BIU and comparisons with reference collection material from the Upper Jordan Valley on the Bank of the Yargon River.
Uses/Ethnographic Examples:	Al-Qura'n (2007) has noted the use of *P. salicifolium* as a medicinal aquatic plant used in Jordan.



Taxon: **Chenopodiaceae spp.**

Family: Chenopodiaceae

Common Name/ Arabic or Local: Name: Goosefoot/ *sha'rān* (for *Anabasis setifera*), *sh/hēbā* used for *Bassia muricata* (Mandeville, 2011)

Measurements: L:1.0-1.2mm, B:1.0-1.3mm, Th:0.5-0.8mm

Description: This broad categorization includes globose, lens shaped seeds. However, spiraled embryos are also included here. On many specimens the testa were absent. This broad identification category likely includes some poorly preserved *Atriplex* spp., and *Salsola spp*. that due to missing diagnostic features were not fully identified. Nelson (1973) lists 27 species from 13 Genera of Chenopodiaceae in the Azraq desert oasis.

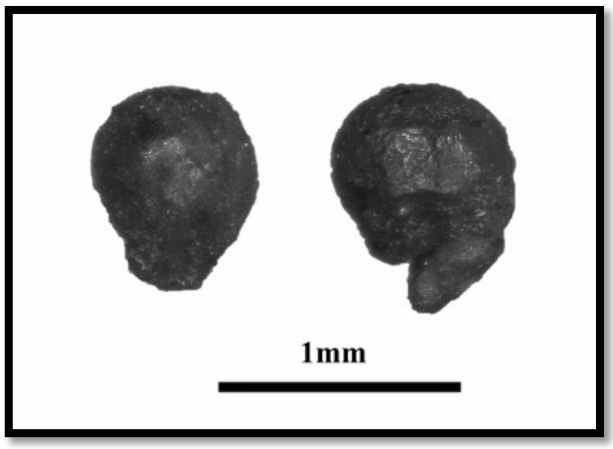
Regional/Temporally Similar Archaeological Occurrences: Colledge (2001) lists Chenopodiaceae/*Capparis* sp. types as present at Wadi Hammeh 27, and Chenopodiaceae/Caryophyllaceae indeterminate, single loop and cf. single loop Chenopodiacea /Crucifer's at Wadi Jilat 6. Kislev *et al*. (1992) also report Chenopodiaceae at Ohalo II.

Geographical Distribution: Chenopodiaceae are present all over Jordan and is one of the dominant families (El-Eisawi, 1996).

Habitat: Widespread from the tropics to cool temperate regions, generally dry temperate and warm temperate areas. Many tolerate salty soils, or grow in dry steppes or semi deserts (Müller and Borsch, 2015). The range of Chenopodiaceae occurring within the Eastern Jordan (Al-Eisawi, 1996), and the Azraq desert oasis (Nelson 1973) are characterised by similar habitat requirements, limiting our palaeoecological interpretation.

Reference Collections Consulted: UCL (Hillman Collection), BIU.

Uses/Ethnographic Examples: Many Chenopodiaceae species are associated with anthropogenic vegetation either as a ruderal or an agricultural weed. *Beta vulgaris* is the only Chenopodiaceae discussed by Tukan *et al.* (1998), as a possible food source. He notes that the leaves and stems are consumed, often in stews and soups and sometimes pastry filling. Nelson (1973) however, does not list any *Beta vulgaris* as present in the Azraq desert oasis.



Taxon: ***Atriplex* sp.**

Family: Chenopodiaceae

Common Name/ Arabic or Local: Name: White-branded orache (Kislev and Simchoni 2002), Saltbush, Spanish Sea Purslane / r*ughl*: are widely used names for *Atriplex leucoclada* (Mandaville 2011) *rghelah*: Used by northern Bedouin tribes for *Atriplex dimorphostegia* (Musil 1927*), Atriplex halimus: Kataf milhi* (online flora of Jordan)

Measurements: L:0.75-0.9mm, B: 0.8-1.0mm, Th: 0.4-0.5mm

Description: Seeds are broadly globose, however, they often appear slightly cordiform/mitaform depending if the radical lobe survives. All seeds are puffed/expanded due to charring. Only one of these *Atriplex* sp. seeds with an outer coating (testa, or impression of part of the pericarp) survived and covers only a small fragment of the seed (pictured second from left). The visibly veined/rugose surface and the UCL reference collection has helped confirm these as *Atriplex* sp. The general shape and surface pattern suggest *A. leucoclada* and *A. tatarica.* Also compared with Wilcox (http://g.willcox.pagesperso-orange.fr/) and van Zeist and Bakker-Heeres (1982).

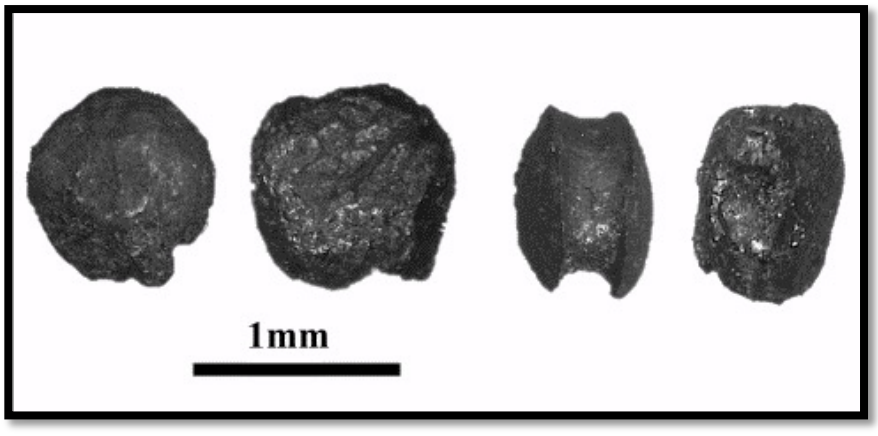
Regional/Temporally Similar Archaeological Occurrences: Kislev *et al.* (1992) report *Atriplex* sect. *rosea* , and *Atriplex leucoclada* (Kislev and Simchoni 2002) as present at Ohalo II. *A. leucoclada* is mentioned by Nelson (1973) as being in the Azraq oasis. Al-Eisawi (1991) describes *Atriplex leucoclada* as typical of Pebble Hammada/Harrah and *Atriplex* spp. typical of Sandy Hammada vegetation in Jordan. *A. Halimus* (online flora of Jordan)

Geographical Distribution: **(*Atriplex* cf. *leucoclada)*** Palestine - Syria/Jordan C. Negev S. Negev Arava Valley Moav Desert (FoT). It is common in the arid areas of the Jordan rift valley, southern and eastern deserts (Al-Esawi 1996).

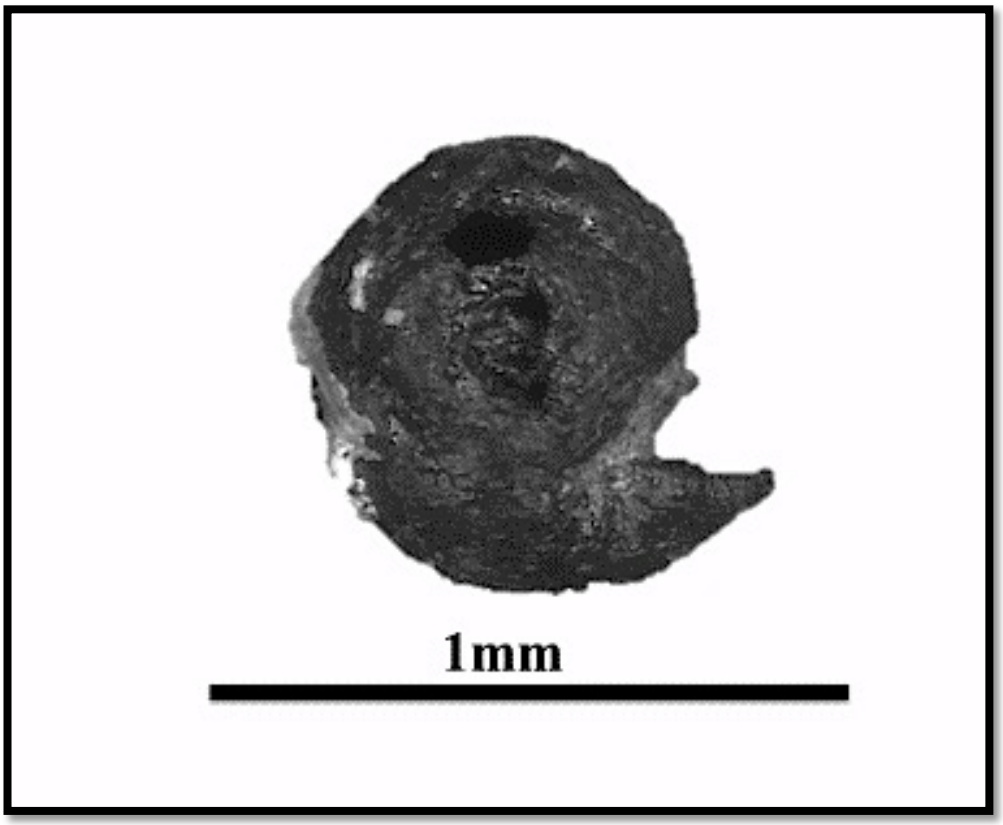
Habitat: Deserts and Wadi beds (FoT)

Reference Collections Consulted: UCL (Hillman Collection), BIU.

Uses/Ethnographic Examples: As Kislev and Simchoni (2002) note, the leaves of *A. leucolada* can be eaten raw or cooked but are not as tasty as *A. halimus* (Zohary 1966, Danin 1983)



Taxon:	***Salsola* sp.**
Family:	Chenopodiaceae
Measurements:	L: 0.6-0.8mm, B: 0.6-0.8mm, Th: 0.2mm
Description:	Laterally compressed with an overall circular shape. The visible embryo is spiraled. Surface does not survive.
Regional/Temporally Similar Archaeological Occurrences:	Nelson (1973) lists these 3 species of *Salsola* spp. which are present both in Azraq as well as listed in the FoT: *S. inermis*, *S. tetrandra*, and *S. vermiculata.*
Geographical Distribution:	Palestine - Syria/Jordan Judean Desert W. Negev C. Negev Lower Jordan Valley Dead Sea area, Arava Valley, Ammon, Moav and Edom.
Habitat:	*Salsola* spp. are typical of steppe vegetation (Al Esawi, 1996). Al-Esawi classifies *S. inermis* as present in Jordan and typical of the Saharo-Arabian Region. *S. inermis*: deserts mostly on disturbed ground and ruderal sites. *S. tetrandra*: deserts, dry saline soils. *S. Vermiculata*: calcareous stony steppes and somewhat saline soils. All *Salsola* spp. in FoT, have preference for salty habitats.
Reference Collections Consulted:	UCL (Hillman Collection), University of Bar Illan.
Uses/Ethnographic Examples:	Shoots can bee eaten raw or cooked



Taxon: ***Nitraria schoberi***

Family: Zygophyllaceae

Common Name/ Arabic or Local: Name: Salt grape/ ***msa', ghardag*:** name recorded by Mandaville (2011) in Saudi Arabia *for* the similar species of *Nitraria retusa*; Palgrave (1862) used the name ***msa'*** (1865, 1:30); ***tal'*:** The name recorded by Musil (1928a,95) used by the Ruwalah Bedouin.

Measurements: L: 5.7mm, B: 2.9mm, Th: 2.9mm

Description: These are the largest seeds found at KHIV, They are obovoid in form. The apex of the seed is rounded. The surface is pitted/scrobiculate and narrows to a multi-pronged, 3-sided point.

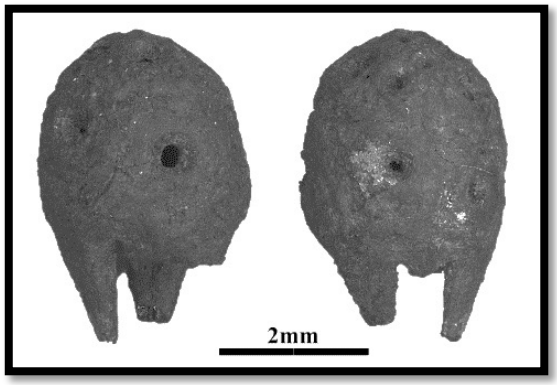
Regional/Temporally Similar Archaeological Occurrences: *Nitraria schoberi* is documented at Ohalo II (Kislev et al. 1992) and its differences with N. *retusa* are discussed by Kislev and Simchoni 2002). *N. retusa* is documented in the Azraq Oasis (Nelson,1973) and is also discussed by Kislev and Simchoni (2002). A unique occurance of *N.schoberi* was reported at Azraq Shishan (Tackolm et al. Kew herbarium sheet 9101; see also Zohary 1973).

Geographical Distribution: Irano-Turanian. Turkey, Syrian desert, S Russia, Crimea, Caucasia NW Iran, C Iran, Siberia, C Asia.

Habitat: Sandy or salty places. Kislev (1992) has suggested that for Ohalo II the presence of *N. schoberi* instead of the local *N. retusa* confirms the climate was cold and dry (www.biu.ac.il/js/archaeo/ohalo.htm). Kislev and Simchoni (2002) also note that *N. schoberi* is restricted to sites where the ground water is brackish or moderately salty. In Iran it is common in marshy spots in dry river beds.

Reference Collections Consulted: UCL (Hillman Collection), BIU.

Uses/Ethnographic Examples: Shishkin et al. (1970) described *N. schoberi* as having edible pale red juice. Palgrave (1862) described *N. retusa* fruits as similar to a red currant and describes the Bedouins as "greedily devouring it" and making a molasses type syrup (1865, 1:30); Musil (1928a, 95) recorded its use by the *Ruwalah* Bedouin's and describes it as very sweet with bitter aftertaste, boiled into thick syrup. In Saudi Arabia *N. retusa* is also recorded as being eaten by the Bedouin (Mandaville (2011).



Taxon: **cf. Leguminosae (Large)**

Family: Leguminosae

Common Name/ Arabic or Local: Name: Legume, Pea, Bean family

Measurements: L: 2.9mm, B: 2.9mm, Th: 1.8mm

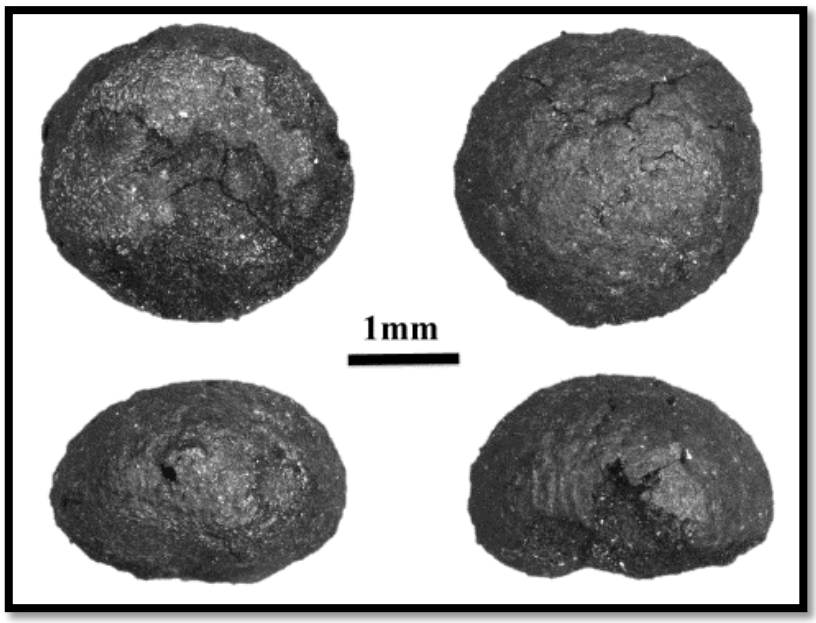
Description: This single seed from Area A is reminiscent of a *Lens*/lentil type seed. It is globose, and transversely narrowly eliptic. There is no hilum visible, and the seed is incomplete and poorly preserved.

Habitat: Worldwide distribution (except Antarctica and high Artic), shrubs predominantly outside tropics.

Regional/Temporally Similar Archaeological Occurrences: Various Leguminosae spp. are listed by Nelson (1973). In addition at Wadi Hammeh 27 Colledge (2001) noted Lens sp., Leguminosae indeterminate, and Leguminosae small. In the Hayonim Cave (Hopf and Bar-Yosef, 1987) also noted a cf. *Pisum* sp. At the Kebara Cave, Lev *et al.* (2005) reported that the majority of the identified seeds (a total of 18 taxa) were legumes

Reference Collections Consulted: UCL (Hillman Collection), BIU, UoN.

Uses/Ethnographic Examples: In general legumes can be consumed as young shoots, ripe or mature pods, seeds/fruits; dried roots (*Glycyrrhiza glabra* (Licorice); fruits and shoots. See Tukan *et al.* (1998) for a list of various edible wild Leguminosae in Jordan.



Taxon: **cf. Leguminosae (Small)**

Family: Leguminosae

Measurements: L: 0.49mm, B: 0.3mm, Th: 0.2mm

Description: This general identification was given to a single poorly preserved and very small legume shaped seed. It had a depression, reminiscent of a hilum. (no photo)

Taxon: ***Lotus* cf. *corniculatus***

Family: Leguminosae

Common Name/ Arabic or Local: Name: Birds foot, trefoil

Measurements: L:1.5mm, B: 1.0mm, Th: 0.6mm

Description: Mitaform in shape and broadly oblong. While at Bar Ilan, I inspected a reference collection specimen *of Lotus tenuis* (known as *L.corniculatus* in the FoT) from Golan, which matched the general shape, size and in particular, had a very similar, prominent hilum.

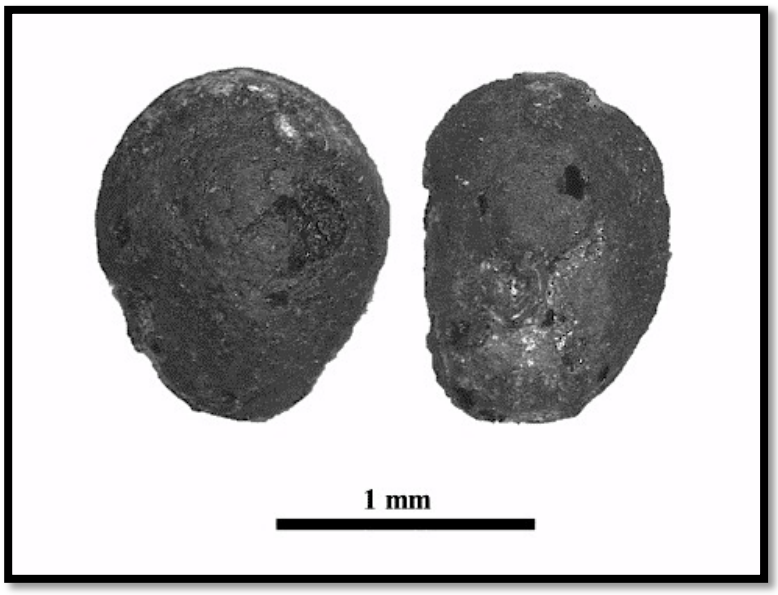
Regional/Temporally Similar Archaeological Occurrences: Nelson (1973) mentions *Lotus* cf. *corniculatus* in the Azraq Desert Oasis Vegetation survey.

Geographical Distribution: Irano-Turanian phytogeograpical zone. Turkey, Europe, N Africa, W Asia, C. Asia.

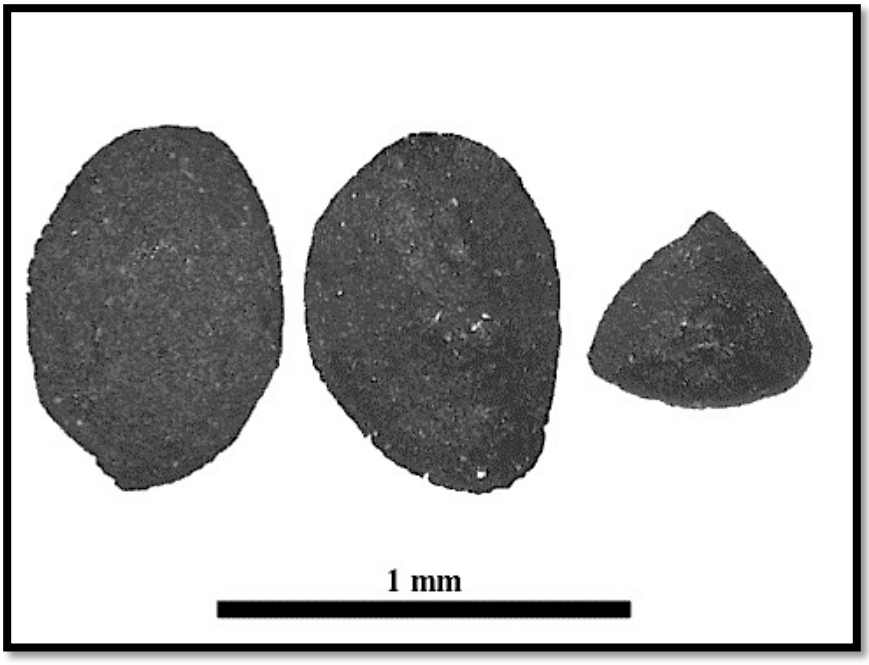
Habitat: Prefers humid, damp heavy soils, river banks and marshes (FoT, Danin 2013), Perennial

Reference Collections Consulted: UCL (Hillman Collection), BIU

Uses/Ethnographic Examples: Seed pods are edible, but large quantities are toxic (Schultes,1984), contains cyanogenic glycosides which stimulates respiration and improves digestion (Chiej, 1984).



Taxon:	***Anagallis* sp.**
Family:	Primulaceae
Common Name/ Arabic or Local: Name:	Scarlet pimpernel
Measurements:	L: 0.9-1.2mm, B: 0.7-0.8mm, Th:0.2mm
Description:	The overall shape of these seeds was elliptical/rhombic, with a pointed, but not steep, apex. The *Anagallis* sp. found at Kharaneh IV, are uniformly missing their outer coating (which should be covered in bumpy scales), however without the outer coat they appear rather smooth. They lie flat only on their ventral face. Size wise, the seeds appear to be *A. arvensis*. A similar but too large and too oval option was *Lysimachia foemina*.
Regional/Temporally Similar Archaeological Occurrences:	Nelson (1973) mentions *Anagalis arvensis as present* in the Azraq Desert Oasis Vegetation survey (Al-Esawi 1996).
Geographical Distribution:	FP: Typical of Mediterranean, Saharo-Arabian and Euro-Siberian phytogeograpical zones, naturalized to other parts of the globe/FoT: Turkey Europe NW Africa Syria Lebanon Iraq Iran Afghanistan.
Habitat:	Mostly marshy or irrigated alluvial soil (FP, Taifour and El-Oqlah, 2014), cultivated land river banks clay soil rocky slopes (FoT).
Reference Collections Consulted:	UoN, UCL (Hillman Collection), UBI.
Uses/Ethnographic Examples:	Folk medicine, toxic, mentioned in the Tirukkuṛaḷ (Watt *et.al.* 1962). The only wild and edible Primulaceae listed by Tukan *et al*. 1998 is the *Cyclamen persicum,* which has edible leaves and soft seeds today in the Mediterranean and Eastern Levant the leaves are filled with rice and meat (similar to Greek dolmades) (Ali-Shtayeh et al. 2008)



Taxon: ***Lithospermum* sp. (mineralized)**

Family: Boraginaceae

Common Name/ Arabic or Local: Name: Stoneseeds , Borage /?

Measurements: L: 2.0-2.2mm, B: 1.6-1.9mm, Th:1.3-1.7mm

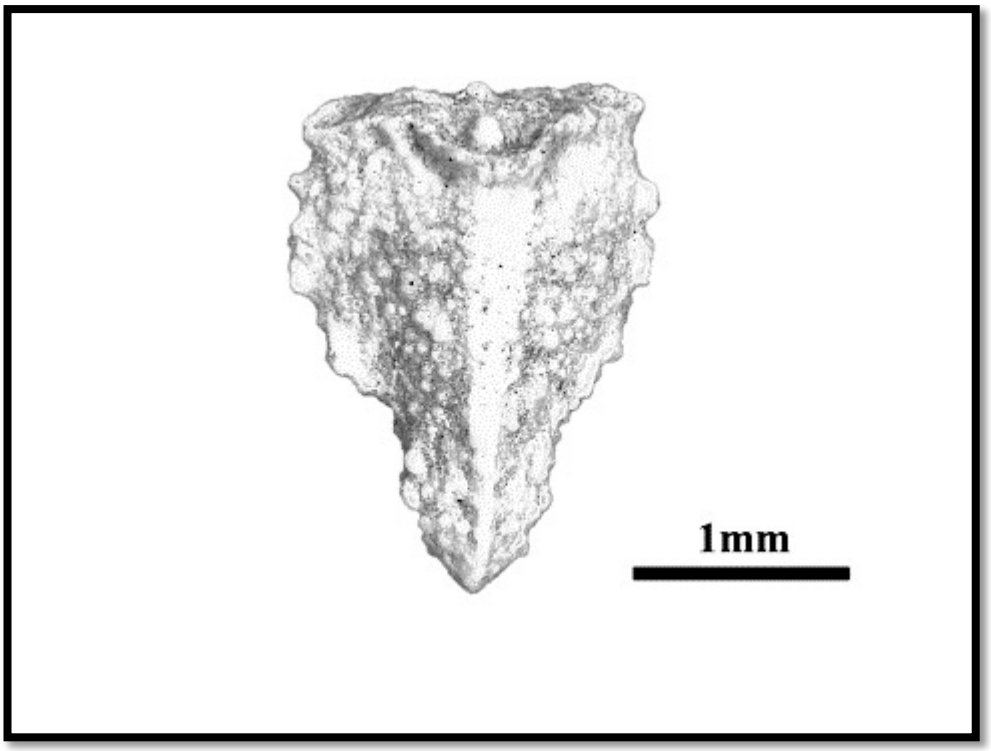
Description: In outline these seeds are angular/diamond shaped, and in cross-section, triangular. They all have a flattish basal surface with a pinched micropylar border and an open hilum. They are covered in small bumps. The edges are pinched. At Bar Illan I compared these to *Buglossoides incrassota,* which appeared relatively similar in overall shape and size. These also bear resemblance to *Buglossoides arvensis.* The *Lappula spinocarpos* looks very similar. None of these seeds showed any sign of charring and are therefore reported here, but further analyses bares this in mind, as they may be contaminants.

Regional/Temporally Similar Archaeological Occurrences: Boraginaceae are present in Jordan (El-Asawi 1996). Nelson lists 10 species of Boraginaceae in the Azraq Oasis, but does not list any *Lithospermum*. sp. *Buglossoides arvensis* are present at Wadi Hammeh 27 (Colledge 2001) but were not included in analysis in case of contamination.

Geographical Distribution: Turkey Europe N Africa SW Asia C Asia

Habitat: limestone slopes, field margins, rocky, steppe

Reference Collections Consulted: UCL (Hillman Collection), BIU



Taxon: **cf. Labiatae/*Eragrostis* sp. Type**

Family: Labiatae/Graminae

Common Name/ Arabic or Local: Name: Possible candidates: *Calamintha incana* (Grey moench), *Micromeria nevervosa* (Benth), *Origanum syriacum* (Thyme.Syrian hyssop), *Salvia fruticose* (Sage, Lebanon sage), *Salvia hierosolymitana* (Clary, Judean sage) (Tukan *et al*. 1998, Danin and Kuune 1996):

Measurements: L:0.8mm, B: 0.45mm, Th: 0.15mm

Description: These seeds are obovate with a subtle point/pinch just below the embryo. The embryo is wide and extends ½ the seed length and a slight ridge extends across the entire concave ventral side. The dorsal side is convex with a ridge running lengthy wise. After consulting with Sue Colledge and the Labiatae from Abu Huyera and UCL reference collections cf. Labiatae was assigned, however, at Bar Ilan, Yoel Melamed suggested that it might be a small, flattish, Poaceae such as *Eragrostis* spp. I compared it with *Eragrostis turgida* from the Bar Illan reference and they appear quite similar both in size and shape. However, due to very low numbers and not being able to compare the physical seeds while in Israel a categorization title of cf. Labiatae/*Eragrostis* sp. type, was assigned to this seed.

Regional/Temporally Similar Archaeological Occurrences: Labiatae spp. are present in Jordan (Al-Eisawi, 1996), Hillman *et.al* (2000) reported some Labiatae indeterminate at Abu Huyera.

Habitat: *Eragrostis turgida* : cultivated/disturbed areas (Burkil 2004), Labiatae *Phlomis* spp, *Thymus* spp. types: steppe/dry/ cultivated/disturbed (FoT)

Reference Collections Consulted: UCL, Bar Ilan

Uses/Ethnographic Examples: The following wild and edible Labiatae's are commonly used in Jordan today (Tukan *et al.* 1998, Danin and Kuune 1996): *Calamintha incana* (Grey moench)-Leaves and roots; *Mentha longifolia* (wild mint)- stems and leaves; *Micromeria nevervosa (*Benth)- Stems and leaves; *Origanum syriacum* (Thyme.Syrian hyssop)-young stems and leaves; *Salvia fruticose* (Sage, Lebanon sage)- leaves and shoots; *Salvia hierosolymitana* (Clary, Judean sage)-leaves. *E. turgida* is a famine food in west Africa and is collected and used as a cereal (Burkil, 2004).



Taxon: **Cyperaceae sp.**

Family: Cyperaceae

Common Name/ Arabic or Local: Name: Sedges

Description: (No Photo) This classification represents poorly preserved Cyperaceae seeds. As a whole, they are roughly obovoid and sit flat on their ventral surface These seeds were reminiscent of *Carex* sp. but could not be further identified. (no photo)

Habitat: Wetlands, riparian, Marshy grassland, areas with poor soil (Jermy *et al.* 2007).

Taxon: **cf. Cyperaceae core Type 1**

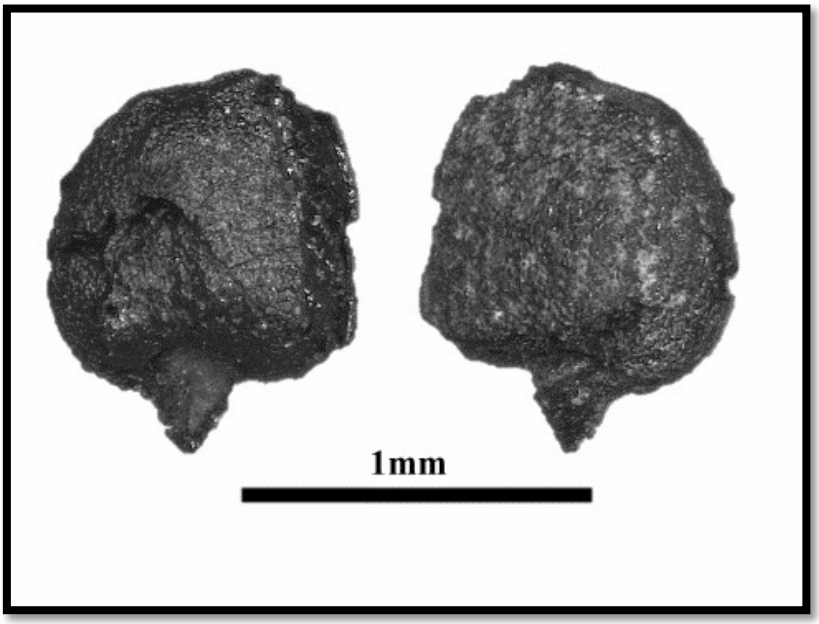
Family: Cyperaceae

Measurements: L: ?, B: 0.8-1.1mm, Th: 0.3-0.4mm

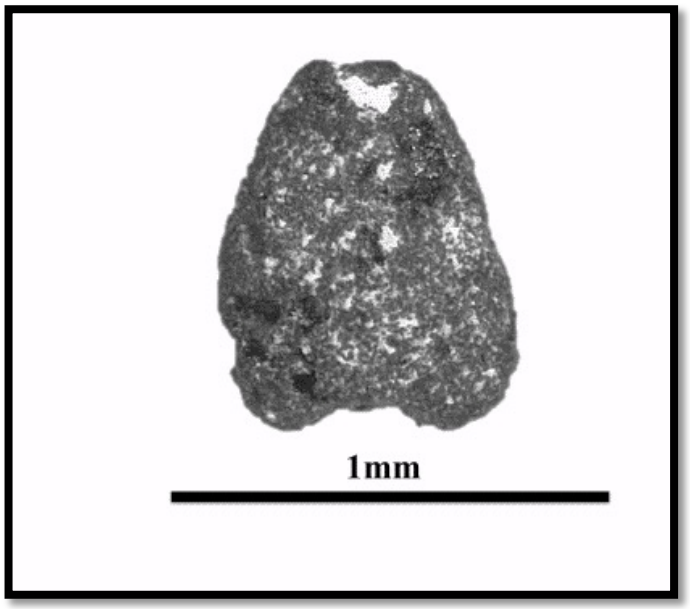
Description: These seeds are poorly preserved and the overall shape is deceptive. It appears the seed was obovoid, but is now cordiform due to preservation. The surface, where it survives, appears wrinkled with rows of colliculate cells reminiscent of the *Carex* spp. seeds identified herein.

Habitat: See: Cyperaceae- Wetland

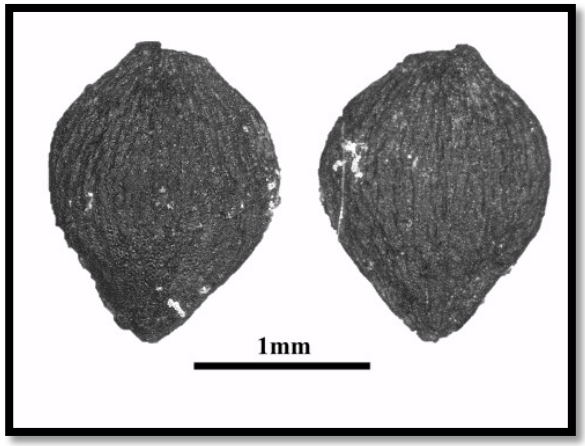
Reference Collections Consulted: UCL (Hillman Collection), BIU

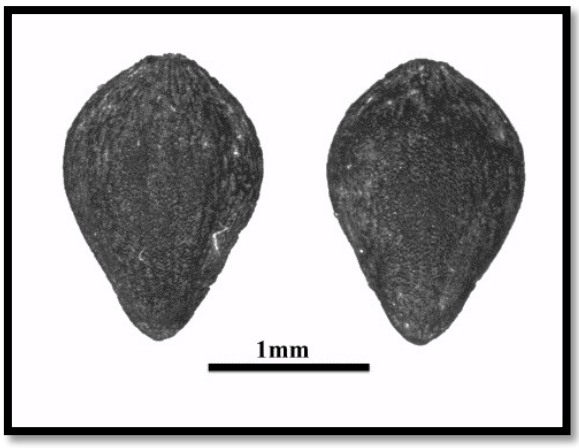


Taxon:	**cf. Cyperaceae core Type 2 (Long)**
Family:	Cyperaceae
Measurements:	L:0.85mm, B:0.65mm, Th:0.2mm
Description:	It is cordiform in shape with a blunt apex, poorly preserved. *Cyperus longus* is listed as present in the Azraq basin, and representative of water vegetation (Hydrophytic) El-Asawi (1996)
Habitat:	See: Cyperaceae- Wetland
Reference Collections Consulted:	UCL (Hillman Collection), BIU.

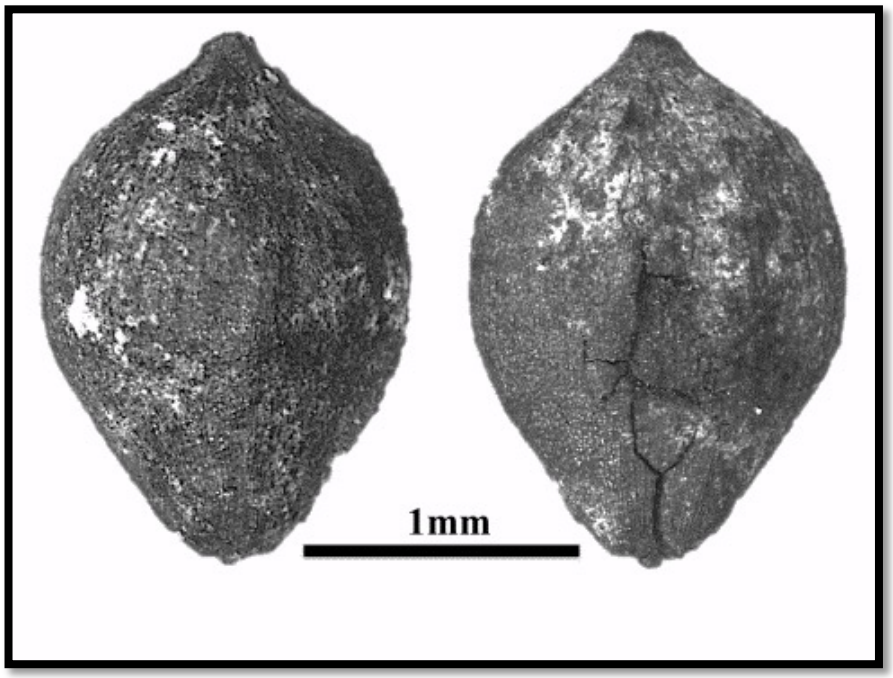


Taxon:	***Carex* cf. *divisa***
Family:	Cyperaceae
Common Name/ Arabic or Local: Name:	Sedge, Divided or separated sedge
Measurements:	L:1.8-1.2mm, B:0.9-1.3mm ,Th:0.3-0.5mm
Description:	*Carex* seeds (nutlets) are notoriously difficult to identify to the species level. The two seeds below are representative of the range of *Carex* cf. *divisa* at Khareneh IV. Some are slightly wider, but all sit flat, if slightly concave on their ventral surface with a convex dorsal side. There is a colliculate surface with cells in long narrow rows running vertically. The attachment points are missing in all samples and sharp breaks are apparent.
Regional/Temporally Similar Archaeological Occurrences:	Present in Nelson's 1973, Azraq Oasis survey along with 2 other *Carex* spp. (*C. hispida*, *C. stenophylla*). Two types of Cyperaceae were noted at Wadi Jilat 6 (Colledge, 2001) but were not further identified.
Geographical Distribution:	Euro-Siberian phytogeograpical zone Turkey WS C Europe S Russia Mediterranean SW Asia
Habitat:	Marshes, ditches by streams, saltmarshes (FoT, FP). Wetlands, riparian, marshy saline meadows by soda lakes, and grassland ditches (Jermy et al. 2007).
Reference Collections Consulted:	UCL (Hillman Collection), BIU





Taxon:	***Carex* cf. *hispida* Type**
Family:	Cyperaceae
Common Name/ Arabic or Local: Name:	Sedge
Measurements:	L: 1.6-1.8mm, B: 1.0-1.3mm, Th: 0.3-0.5mm
Description:	As noted already above, *Carex* sp. seeds (nutlets) are notoriously difficult to identify to the species level. The beak/ surviving attachment points are present. The overall shape is obovoid. There are as vertical rows of coliculate rows of cells visible. A slight dorsal ridge that hints towards *C. hispida*. The ventral side is relatively flat, however, there is some puffing, which makes concave and convex sections.
Regional/Temporally Similar Archaeological Occurrences:	As with the *Carex* cf. *divisa*, *Carex. hispida*, *Carex stenophylla* are present in Nelson's 1973, Azraq Oasis survey. Two types of Cyperaceae were noted at Wadi Jilat 6 (Colledge, 2001) but were not identified.
Geographical Distribution:	Turkey, Mediterranean
Habitat:	Marshes, ditches by streams, saltmarshes (FoT, FP). Wetlands, riparian, Marshy saline meadows by soda lakes, and grassland ditches (Jermy et al. 2007).
Reference Collections Consulted:	BIU. see: Jacomet *et al*. (1989:317) for lengths and widths for narrowing *Carex* species –however this is for Europe)



Taxon: **cf. Gramineae (*Pooideae*?/*Setaria*? Type)**

Family: Gramineae

Measurements: L: 0.9mm, B: 0.45mm, Th: 0.2mm

Description: A large embryo is visible on one side and a faint depression on the opposite side suggesting a ventral furrow or linear hilum. Poor preservation and a very small seed. However, my interpretation in consultation with Mark Nesbitt and Sue Colledge, is that this is a Gramineae. Despite being smaller than Nesbitt's (2006) examples, this seed is reminiscent of a *Setaria* spp. There are 7 species of *Setaria* sp. listed in the FoT. Unfortunately, there is only one of these seeds, so further analysis and comparison was not practical.

Regional/Temporally Similar Archaeological Occurrences: *Setaria* spp. are present at Ohalo II (Kislev et al. 1992) and Abu Huyera (Moore et al.)

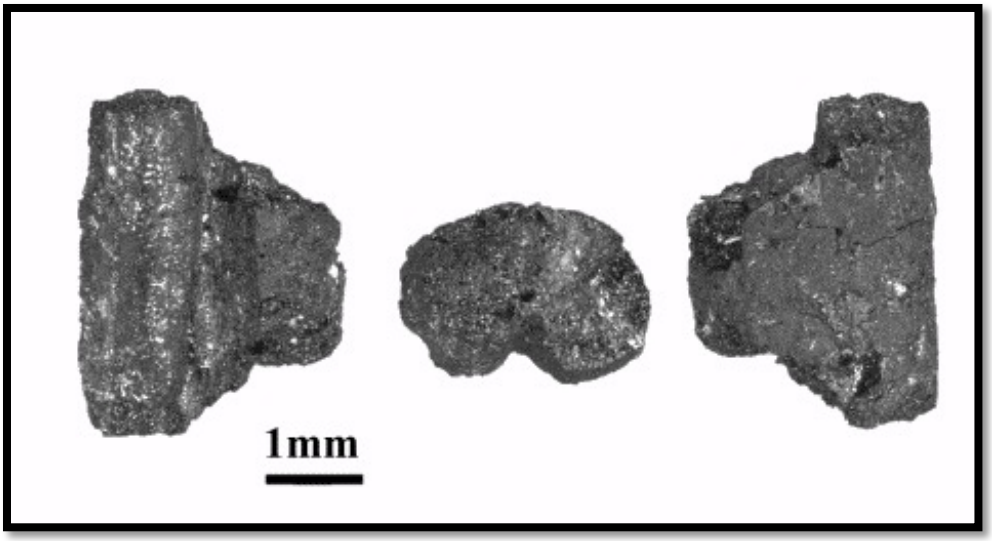
Geographical Distribution: Global distribution/ for *Setaria* spp. Turkey Mediterranean Caucasia SW Asia Sinai Arabia Africa C Asia E Asia.

Habitat: Pooideae: Cool weather grass, disturbed ground. *Setaria* sp.: Weed in cultivated fields and gardens, waste places, disturbed areas and along roads (Holm et al., 1977).

Reference Collections Consulted: UCL (Hillman Collection), BIU.



Taxon:	**cf. *Taeniatherum* sp.**
Family:	Gramineae
Common Name/ Arabic or Local: Name:	Medusahead / NA
Measurements:	L:? B: 2.5mm Th: 1.6mm
Description:	This fragment of a large seeded grass is characterized by surface grooves, a linear hilum, dorsally compressed and a very wide and shallow ventral groove. Here is only a single seed fragment of this. A large Gramineae. The apex and embryo are missing which makes a certain identification impossible.
Regional/Temporally Similar Archaeological Occurrences:	FoT notes one species of *Thaeniatherum, T. caput-medusae.* Savard *et al*. (2003) notes its presence at Neolithic M'lefaat (Iraq). And Riehl *et al*. (2012) for similar image, and is noted in Baines's assessment in the Zagros (2015).
Geographical Distribution:	Turkey C Europe SE Europe N Africa Caucasia Iran Iraq Afghanistan C Asia
Habitat:	Steppe grassy mountain slopes, stony hillsides, mountain scrub, sandy plains (FoT), Grassy slopes on dry stony soils (Nesbitt, 2006).
Reference Collections Consulted:	UCL (Hillman Collection), BIU, I also compared this with the images from Wilcox's online database (http://g.willcox.pagesperso-orange.fr/). Based on its size and in consultation with M. Nesbitt in person and his identification guide (2006) we compared to M. Savard's PhD. Images from Abu Huyera.



Taxon: ***Hordeum* spp.**

Family: Gramineae

Common Name/ Arabic or Local: Name: Barley, *sha'ir (Hordeum* spp.*)*

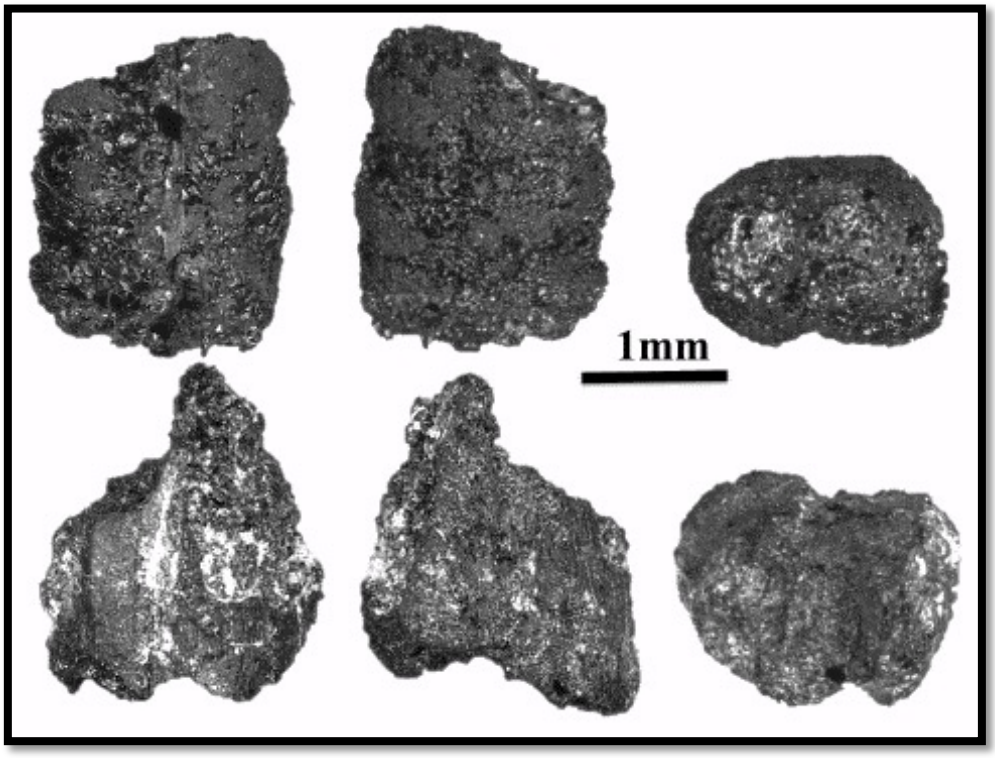
Measurements: L:? B: 1.5-2.0mm, Th: 1.2-1.5mm

Description: No complete *Hordeum* sp. seeds were found, however, these fragments suggest the general morphology is consistent with the reference material from Abu Huyera and the Hillman collection at UCL. These were all dorso-ventrally compressed and the ventral grooves are wide and shallow. This is consistent with van Zeist and Bakker-Heeres (1984, 186-87) description of *Hordeum spontaneum*. However, the thickness of the *Hordeum* sp. found at Kharaneh IV is slightly wider than the wild barley reported by Colledge (2001), which were recorded as no wider than 1.0mm.

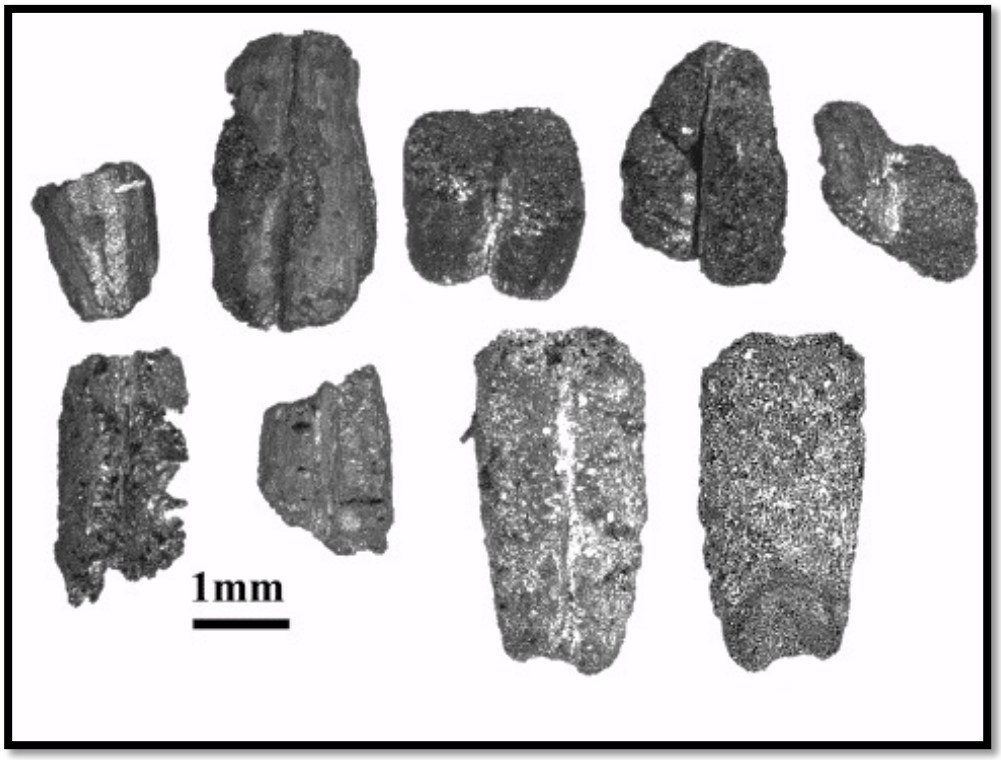
Regional/Temporally Similar Archaeological Occurrences: Nelson 1979, identified 3 species of *Hordeum* in the Azraq Oasis : *H. glaucum., H. leporinum.,*and *H. spontaneum. Hordeum* spp. are present at Ohalo II, Hayonim cave, Wadi Hammeh 27, Wadi Jilat 6

Habitat: Steppe river banks lake margins fields roadsides

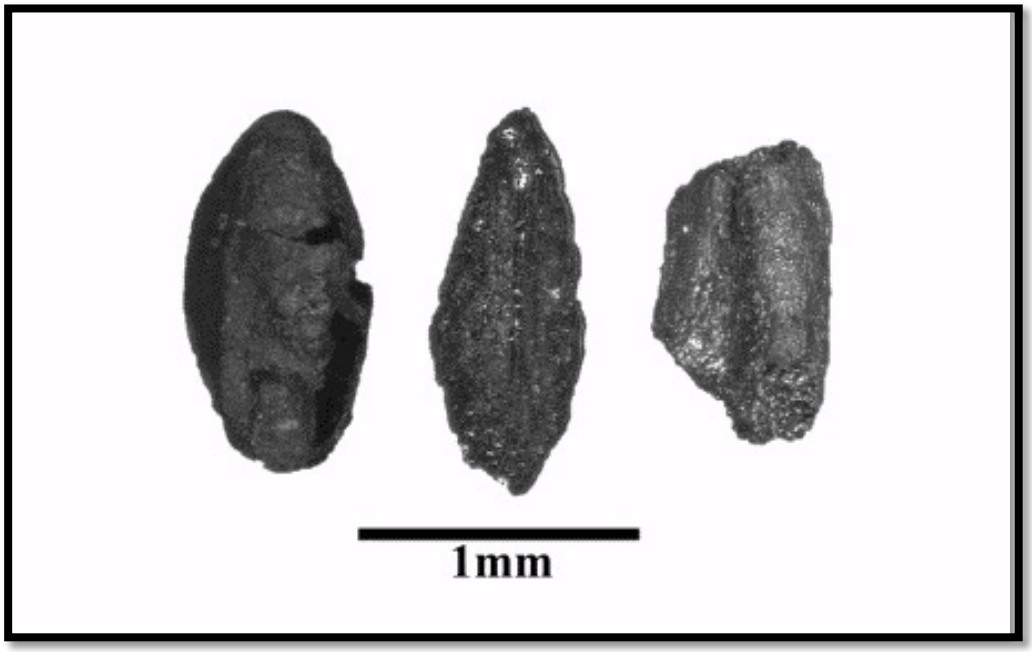
Reference Collections Consulted: UCL (Hillman Collection), BIU.



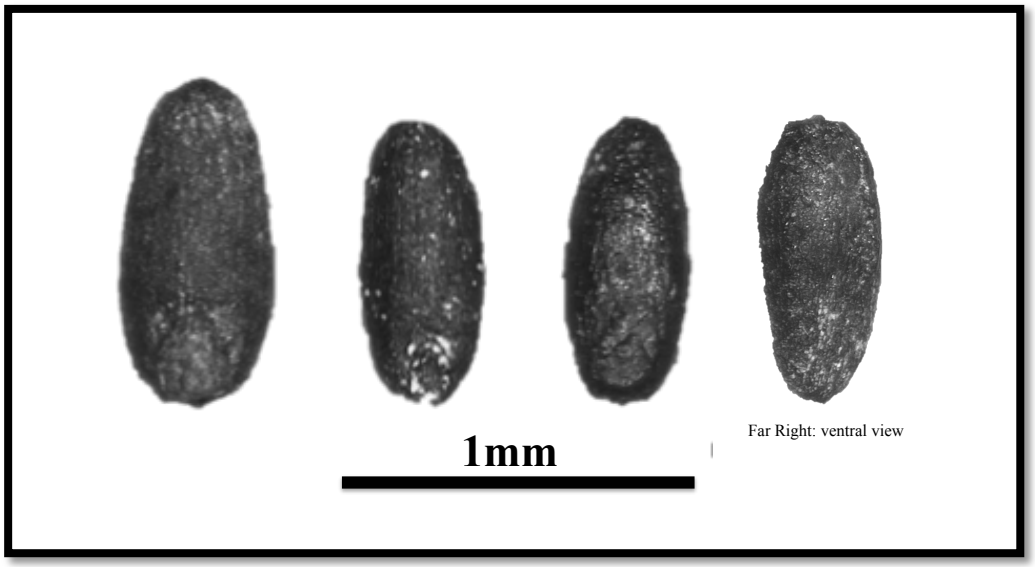
Taxon:	**Gramineae Large**
Family:	Gramineae
Common Name:	Grass
Measurements:	>1.5m
Description:	There are 44 species and 26 Genera of Gramineae identified by Nelson (1979) in the Azraq oasis. This category of Gramineae is based on size. All specimens in this category are missing either their apex or embryo, or both. They have clear ventral grooves present, which allow them to be placed in Gramineae. It is likely that these seeds represent various species.
Reference Collections Consulted:	UCL (Hillman Collection), BIU and discussions with Mark Nesbitt (Kew).



Taxon:	**Gramineae Medium**
Family:	Gramineae
Common Name:	Grass
Measurements:	L:1-1.5mm
Description:	This category is based on size. These seeds do not exceed 1.5mm in length. Despite a few complete seeds, preservation was poor. They have clear ventral grooves present, which allow them to be placed in Gramineae. It is likely that these seeds represent various species and the photo here serves only as the best representative examples.
Reference Collections Consulted:	UCL (Hillman Collection), BIU and discussions with Mark Nesbitt (Kew).



Taxon:	**Gramineae Small**
Family:	Gramineae
Common Name:	Grass
Measurements:	L: <1mm
Description:	This category is based on size. These seeds are all less than 1.0 mm in length. These grasses are very tiny and within this category all of the seeds are complete with an apex and embryo. They have clear ventral grooves present, which allow them to be placed in Gramineae. It is likely that these seeds represent various species and the photo here serves only as the best representative examples
Reference Collections Consulted:	UCL (Hillman Collection), BIU and discussions with Mark Nesbitt (Kew).



Taxon: **cf. Compositae Kernel**

Family: cf. Compositae

Measurements: L: 3.2-5.0mm, B:1.4-2.0mm, Th: 1.4-1.2mm

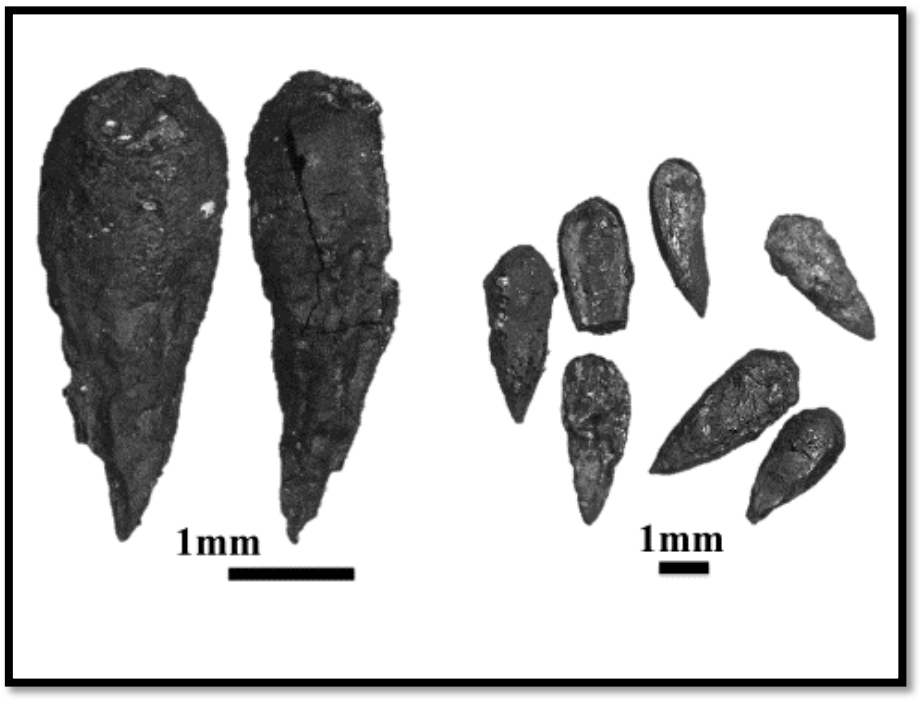
Description: Conical/narrowly obtruilate with a wrinkled, and sulcate like surface. The Kharaneh IV seeds matched in size and overall appearance, but with no diagnostic features, there is much variety even within what I had classed as one potential species. I have some reservations about whether these are a) the same species and b) if they are seeds at all. Isotopic analysis showed that their $\delta^{13}C$ was extremely wide ranging, suggesting the seeds I analyzed were not of the same species.

Regional/Temporally Similar Archaeological Occurrences: The FoT lists three species of Compositae, which occur in Palestine, Syria and Jordan: C. *Gymnarrhena,* C. *Asteropterus,* C. *Varthemia*.

Habitat: Compositae have a worldwide distribution except Antarctica and the extreme Arctic. Especially numerous in the Levant (Jose and Crozier. 2012).

Reference Collections Consulted: UCL (Hillman Collection). Initial identifications were made at UCL using Abu Huyera material as a reference where Gordon Hillman found very similar 'Compositae kernels', BIU.

Uses/Ethnographic Examples: Compositae offer a very wide range of uses in Jordan and today the following wild species are still eaten (Tukan *et al.* 1998) *Centaurea iberica* (Spanish thistle)-fleshy leaf petioles and young stems; *Cichorium pumilum* (dwarf chicory)-young leaves; *Gundelia tournefortii* (Gundelia)- young stems and flowers; *Lactuca tuberosa* (wild lettuce, whole plant; *Matricaria aurea* (Chamomile)-whole plant; *Notobasis syriaca* (Syrian thistle)-young leaves, stems and heads; *Scolymus maculatus* (Golden thistle)- young stems; *Scorzonera papposa* (vipers grass)-whole plant; *Silybum marianum* (Holy thistle)-young leaves and stems; *Tragopogon coelesyriaca* (goats beard)-whole young plant

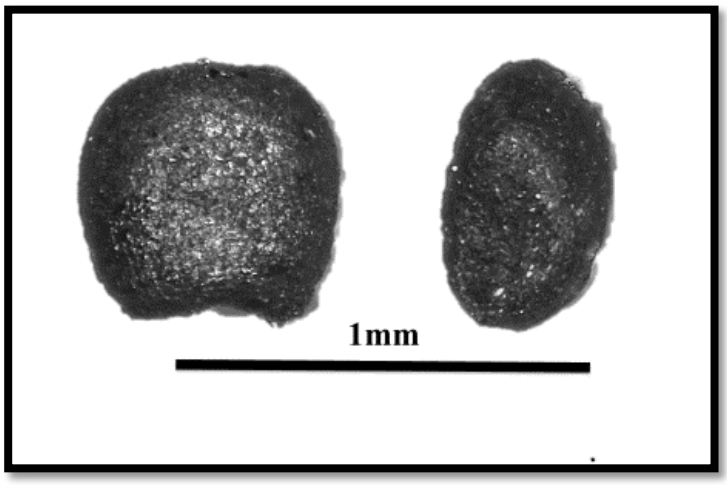


Taxon: **Small Seed Core Type**

Measurements: L:0.65mm, B:0.65mm, Th:0.3mm

Description: Small cordiform shape, blunt apex. Embryo appears to be wide and the texture is reticulate. Reminiscent of *Malva* sp. but the embryo area is very different (too wide).

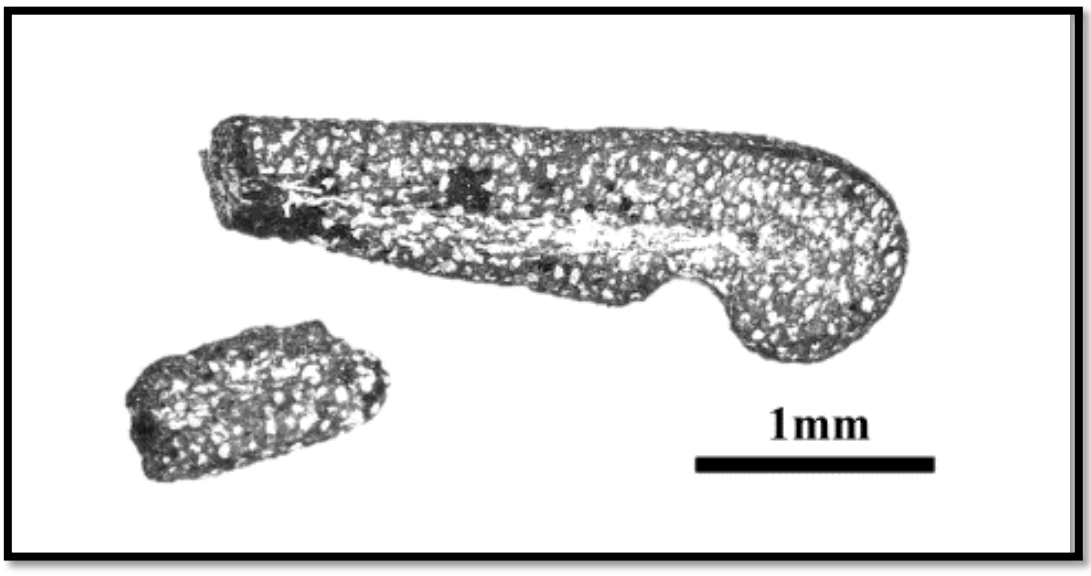
Reference Collections Consulted: UCL (Hillman Collection), BIU.



Taxon: **Reticulate 'hook' fragments**

Measurements: Fragments are 1.0-4.0mm long.

Description: These stick like fragments with a distinctive reticulate surface are present throughout many samples. The image shows one of the most intriguing fragments, as it has a curved head/end and a small notch. I have, without any success shown these to as many archaeobotanists as possible.



Taxon/specimen type: **cf. Fruit Flesh Fragment**

Measurements: L:3.0, B:2.7, Th 1.5

Description: These small vitreous fragments are characterized by having one side covered with an uneven reticulate surface and the other a more rugose and wrinkled surface (exocarp), characteristic of fruit flesh. This particular specimen has a bunching/pinch point that is reminiscent of an attachment point (pedicel/stem) or style remnant.

Regional/Temporally Similar Archaeological Occurrences: Martinoli (2004)- *Pyrus* fruit flesh in S.W Anatolia (Epipalaeolithic)

Reference Collections Consulted: UCL (Hillman Collection), BIU.

Uses/Ethnographic Examples: For Jordan, Tukan *et al*. (1998) note the collection and consumption of the following ripe wild fruits: *Arbutus andrachne* (oriental strawberry tree), *Ziziphus lotus* (ziziphus), *Crataegus aronia* (hawthorn), *Pyrus syriaca* (wild pear)

