Plant gathering and people-environment interactions at Epiplaeolithic Kharaneh IV, Jordan

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Abstract

This paper presents the first archaeobotanical (plant macroremains other than charcoal) results from the Early and Middle Epipalaeolithic site of Kharaneh IV in the Azraq Basin, one of the largest Epipalaeolithic sites in the southern Levant and one of the few with evidence for multiple phases of occupation. The analysis of the substantial archaeobotanical assemblage recovered provides new insights into the local environmental conditions and how these changed throughout occupation, potentially impacting on the use of the site, and further contributes to debates about hunter-gatherer lifeways during the earlier Epipalaeolithic. A variety of potential food plant resources was identified, including several starch-rich fruits, grains and tissues, other fruits, and various other wild seeds. Comparison of the Kharaneh IV archaeobotanical assemblage with those from other Epipalaeolithic sites in the southern Levant reveals a number of similarities and differences. These comparisons, and especially with the coeval, nearby site of Wadi Jilat 6, support the emerging picture of an ecological mosaic within the Epipalaeolithic Azraq Basin, and a general pattern of local resource use across the wider region.

Keywords: Epipalaeolithic, hunter-gatherers, southern Levant, archaeobotany, plant resources, local environment

Declarations

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Introduction

The Late Epipalaeolithic has often been discussed as a period of departure from Early and Middle Epipalaeolithic practices, with significant changes in terms of habitation patterns and symbolic/ritual behaviours that gradually led to the emergence of farming (Asouti and Fuller 2012; Maher et al. 2012a). However, increasing evidence from the southern Levant, encompassing modern-day southern Syria, Palestine, Israel and Jordan, suggests that the earlier Epipalaeolithic periods may not have been so different to the Late Epipalaeolithic (e.g. ibid.). Research at the site of Kharaneh IV, the focus of this paper, has been instrumental in shedding light on these earlier periods and introducing a different narrative, with the excavations revealing the earliest hut structures in Jordan, evidence for repeated occupation and potentially symbolic behaviours, such as caching (Maher et al. 2012b).

Evidence of plant gathering practices and the interaction of people with their environment are crucial issues in furthering our understanding of hunter-gatherer choices, such as habitation patterns and resource management. The rare botanical preservation and clear stratigraphy of Kharaneh IV, including obvious living floors, offers an opportunity to address these issues and add valuable new insights into this time period. Kharaneh IV is one of only a few archaeological sites in the southern Levant dated to the Epipalaeolithic period with preserved and published plant macroremains other than charcoal (hereafter referred to as archaeobotanical or plant remains) (Fig. 1; e.g. Colledge 2001; Asouti and Fuller 2012).

Even when considering a broader geographical area than the southern Levant, such macrofossil evidence for plant remains of this age is still relatively scarce. This gap owes much to problems of identification due to taphonomic and preservation issues. These issues are compounded by the fact that systematic sampling strategies have not, until recently, been regularly employed at many Palaeolithic excavations (Weiss et al. 2004b; Pryor et al. 2013; for a more detailed discussion on the reasons for the scarcity of this line of evidence see Arranz Otaegui et al. 2018a). The Kharaneh IV archaeobotanical data are therefore an important addition to a rare resource, and are particularly significant in contributing to debates about hunter-gatherer lifeways during the early phases of the Epipalaeolithic period.

The site

Kharaneh IV lies at the western edge of the Azraq Basin within the Wadi al Kharaneh, which drains eastwards towards Azraq (Fig. 1). It was first excavated in the 1980s under the direction of Mujahid Muheisen (Muheisen 1988a, 1988b) and since 2008 has been excavated as part of the Epipalaeolithic Foragers in Azraq Project (e.g. Maher et al. 2011).

With the exception of the coeval site of Wadi Jilat 6 (e.g. Garrard and Byrd 2013), Kharaneh IV is much larger (21, 000 m^2) than any other contemporary Epipalaeolithic site in the region, which usually range between 600 and $1200 m^2$ in size (Maher et al. 2008). Adding to the importance of Kharaneh IV is the stratigraphy that shows evidence for multiple Epipalaeolithic phases. Excavations thus far have uncovered rich assemblages of stone tools, animal bones including worked bone objects, red ochre, marine shell beads, good botanical preservation including charcoal, and the earliest known hut structures in Jordan (e.g. Maher et al. 2012; Maher et al. 2016).

Bayesian modelling of a series of radiocarbon dates from both sets of Kharaneh IV excavations (Richter et al. 2013) has placed the site occupation between 19,830 and 18,600 cal. BP with 95% confidence (Table 1). 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).

The examination of cementum in gazelle teeth found at Kharaneh IV has allowed examination of aspects of seasonality in hunting, and thus use, of individual occupation layers at the site. This analysis indicated that gazelles were being killed during autumn/winter as well as spring/summer, sometimes within the same context, providing additional evidence to support the possibility that the site was occupied on a multi-seasonal basis (Jones 2012).

Henton et al.'s (2018) results on the seasonal and spatial distribution of gazelle, using isotopic analysis of teeth from Kharaneh IV, further indicated that despite there being some herd mobility, gazelles were present in the vicinity of Kharaneh IV year-round and, thus, able to support aggregations of hunter-gatherers at any or all times of the year.

The phytoliths recovered from the site suggest that the inhabitants of Kharaneh IV exploited local wetland plant resources, including for use in hut building (Ramsey et al. 2018), and plants from the wider surrounding steppe landscape, such as wild cereals and grasses (Ramsey et al. 2016). This paper focuses on the initial archaeobotantical samples collected from the site during the 2009 and 2010 field seasons, to add further detail to understanding of plant use at the site.

During the 2008, 2009 and 2010 seasons the team relocated and reopened Muheisen's old trenches, allowing for correlation of his previous work with the new excavations that have primarily focused on two mounds (Area A and Area B). During these seasons, the team also expanded the old trenches horizontally to expose the site's horizontal stratigraphy and archaeological features. A deep probe into one of the trenches was also excavated, extending down until it reached sterile deposits (Maher et al. 2008, 2009; McDonald et al. 2018).

The environmental setting of Kharaneh IV

Sediment mapping and dating has suggested that the Wadi Kharaneh may have contained areas of open water at, or near the site as it was established (Jones et al. 2016b). Pleistocene wetland deposits, including marls, were identified at the site but the extent and duration of this wetland is yet to be fully established (ibid.). With the relatively nearby central Azraq Oasis also providing persistent water, at least during the early years of occupation at Kharaneh IV (e.g. Jones and Richter 2011), there would have likely been substantial regional environmental resources for the inhabitants to exploit. Migrating animals would have been drawn to these water resources in order to access the water itself and related vegetation (Martin et al. 2010). The area around Kharaneh IV may have thus formed a settlement refugium during the period of the Last Glacial Maximum (LGM) (Maher 2017) providing subsistence resources for the hunter-gatherers in the region (Martin et al. 2010).

The abandonment of Kharaneh IV around 18,600 cal. BP may have been due to environmental factors, as the timing of abandonment coincides with regional evidence of increasing aridification just after the LGM (Richter et al. 2013). Jones et al. (2016b) noted that a substantial drying out of the local environment is reflected in the existence of a silty loam with carbonate concretions, described by Besancon et al. (1989) and Garrard et al. (1985), which has since been deflated. Garrard et al. (1985) suggested that the loam deposits were loess, and based on the available chronological data, would have been deposited after 19 kya BP. There may not have been a simple drying trajectory through the site's occupation history however, as a change in phytolith taxa recovered from the site suggests a shift in environmental conditions between the Early and Middle Epipalaeolithic (Ramsey et al. 2016), with a relative increase in panicoid grasses in the latter period suggesting more precipitation. The detail of the Epipalaeolithic environmental picture at Kharaneh IV is therefore still unclear and the archaeobotanical data presented here can add further to understanding this.

Materials and methods

Recovery and sampling

All undisturbed deposits were fully sampled (100%) for flotation, regardless of volume. Flotation was done in one of Gordon Hillman's original flotation tanks, which was based on French's (1971) design. The flots were collected in textile bags with an aperture of 250 µm. All flots were hung to air dry in the shade.

A selection of floated soil samples was prioritised for zooarchaeological and anthracological study and exported to the University of California, Berkeley. Of these, 95 unique trench/loci samples from the 2009 and 2010 field seasons with good potential for the presence of archaeobotanical material, and from across a variety of contexts, were selected for use in this study in order to ensure that all phases and major contexts would be represented. In total, 41 samples from Area A, representing 14 unique Loci, and 54 samples from Area B, from 42 unique Loci, were studied (ESM1).

Selection of material, identification and quantification

The floated samples were further processed in the Plants Laboratory of the Department of Classics and Archaeology at the University of Nottingham, UK. All samples were sorted for archaeobotanical remains in their entirety with the exception of very few comparatively large samples (soil volume sampled >100l, see ESM1 for volume details), which were divided in two using a riffle-box in order to create a random subsample. One of the two subsamples was sorted and if any seeds were found then the entire sample was fully sorted while in cases where no seeds were found in the subsample, the second half was briefly scanned. If no seeds were encountered then no full sorting was conducted, whereas if any material was found the subsample was fully processed. All seeds, fruits, grains, amorphous burned masses of material of plant origin (thereon 'burnt 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.

Identification of the plant remains was initially conducted with the aid of the modern plant reference collection of the Plants Laboratory based at the Department of Classics and Archaeology at the University of Nottingham, UK, atlases (e.g. 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/). To refine the initial identifications, the modern and charred Near Eastern collections, the Hillman collection of archaeobotanical material from the site of Abu Huyera (Moore et al. 2000), and Gordon Hillman's personal (unpublished) field notes from his fieldwork in the Azraq Basin during the 1980s and 1990s, all held at University College London, UK, were consulted, as well as the reference collection of mostly modern material of the Department of Archaeology, University of Sheffield, UK. Also, the extensive Near Eastern seed collection held at the Bar-Ilan University, Israel, was accessed as well as the highly comparable Ohalo II material. Nomenclature follows the *Flora of Turkey* (Davis et al. 1966-1985), wherever possible. Where different nomenclature was used, this is listed.

Indet. (Indeterminate) and *cf.* identifications were given to remains that did not correspond to all of the identification criteria due to lack of diagnostic features, distortion from charring or poor preservation, or if they presented characteristics of more than one taxon. Selected specimens were photographed using Image Pro Insight 65, at the archaeobotanical laboratory in the School of Archaeology at the University of Oxford, UK.

To maximise the archaeobotanical material that could be included in the analysis, all whole and fragmented (where fragments represent a separate specimen) items were counted, as well as indeterminate remains. Quantification was based on the Minimum Number of Individuals (MNI), considering only diagnostic zones, such as embryo ends, of each specimen. Indeterminate fragmented items 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 all ~1mm in size and were measured in ml due to their small size and rarity. 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.

Data analysis

The range of taxa present, their abundance, density and diversity were examined. To investigate the spatial distribution of the archaeobotanical material across Areas A and B and its temporal distribution across the various zones, the relative density of material was calculated by dividing the density of a taxon in a particular area or stratigraphic zone by the sum of all taxa densities from that area or zone. This measure controls for different amounts of total plant remains extracted from each area or zone, and presents changes in the dominance of taxa. The zones described and used here (Table 1) reflect chronological groups of samples used in this study, zoned to aid discussion of the data (cp. e.g. MacDonald et al. 2018).

The diversity of taxa through time was examined using rarefaction analysis (e.g. Heck et al. 1975; Gotelli and Colwell 2001). Simple taxa density measurements account for differences in the amount of soil but not for the number of plant remains in a sample/zone which could bias results, as the number of taxa is expected to increase with the number of plant remains, especially at small sample sizes (Gotelli and Colwell 2001). Rarefaction curves demonstrate how taxa richness accumulates with increasing sample size (number of plant remains). They are generated by randomly re-sampling the pool of samples 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 plateaus as only the rarest species remain to be sampled (Gotelli and Colwell 2001). Examination of the final curve allows some measure as to the possibility of undiscovered species present in a sample.

The rarefaction curves were created using the 'vegan' package (Oksanen et al. 2017) in R v.3.3.2 (R Core Team 2017).

Finally, using the autoecological approach, analysis was carried out to determine whether the concentration of taxa with different habitat preferences varied among stratigraphic zones, as such changes may be indicative of environmental change. Information on habitat and growing conditions was retrieved from the *Flora of Turkey* (Davis et al. 1966-1985) and other sources (Zohary 1966; Ellenburg 1988; Dallwitz 1980; Grime 2006) to classify taxa as having 'wet', 'dry' or 'varied' (generalist) habitat preferences in order to investigate wet *versus* dry conditions (water availability) at the site through time, a question that has been related to its habitation patterns. Finer classifications were not possible due to limitations on the taxonomic resolution to which seeds or other plant remains could be identified. Once classified, the plant remains density (number of plant remains per litre of soil) and taxa density (number of taxa per litre of soil) were plotted, and chi-square (X^2) tests were conducted to determine if taxa and plant remain counts differed across stratigraphic zones. It should be noted that this classification included all possible categories of taxa and thus it serves as an approximation only as the lack of finer taxonomic identifications prohibits high certainty results.

Results

Overview of the plant assemblage

In total 95 samples were analysed, 41 from Area A and 54 from Area B, yielding 2985 seeds, fruits and other plant items (1928 from Area A and 1057 from Area B) from 3086.4 litres of soil, including at least 16 taxa (ESM1, ESM2). The majority of items were preserved by carbonisation, and only a few items, such as *Lithospermum* sp. fruits, were mineralised (see ESM1). *Capsella/Lepidium* was the most abundant taxon, primarily recovered from Area A, where it was also quite ubiquitous (second after Chenopodiaceae). *Anagalis* sp. and Compositae were among the most abundant other taxa, also among the most ubiquitous (see ESM1), found in Area A, while *Atriplex* sp. and mineralized *Lithospermum* sp. fruits were the most abundant taxa in Area B, being also among the most ubiquitous ones (see ESM1). Chenopodiaceae were frequent and the most ubiquitous in both areas. All major taxa encountered at the site are presented in ESM3, which includes detailed morphological description of each taxon, its measurements (length, breadth and width), notes on its abundance and regional or temporally similar archaeological occurrences, geographical distribution, habitat and ecological data, as well its uses and ethnographic examples. The measurements reflect the average dimensions of the total seeds/fruits/etc. of a taxon present at the site and if there was variation in size, the range of sizes is listed.

Spatial and temporal trends

The spatial distribution of seeds, fruits and other plant remains across the two areas did not indicate any significant pattern (for detailed contextual information see ESM1), however, some interesting trends emerge when the temporal distribution of the assemblage is considered. Chenopodiaceae, followed by Cyperaceae core, *Atriplex* sp., *Nitraria schoberi*, *Capsella/Lepidium* type and finally Compositae are the most common taxa in the deepest stratigraphic zone B3 (Fig. 2, lower Early Epipalaeolithic see Table 1). Zone B2 (middle Early Epipalaeolithic, see Table 1) is characterised by a clear dominance of *Atriplex* sp., followed by Chenopodiaceae and the mineralized *Lithospermum* sp. Zone B1 (upper Early Epipalaeolithic, see Table 1) is dominated again by *Atriplex* sp., followed by Chenopodiaceae, *Lithospermum* sp., Compositae and small Gramineae. This zone has also most *Carex* spp. (*Carex* cf. *hispidia* type, *Carex* cf. *divisia* type and *Carex* sp.). *Capesella/Lepidium* type is the dominant taxon in zone A2, whereas zone A1, that represents the final stages of occupation at Kharaneh IV, also has comparatively high relative densities of *Capsella/Lepidium* type, but also of *Anagalis* sp., Chenopodiaceae, and Compositae fruits (Fig. 3).

Rarefaction analyses (Fig. 4) indicate that B2 is by far the most diverse zone. A1 appears to have the lowest diversity, though there is overlap of standard errors with A2. However, the A1 curve appears to have flattened out, suggesting that even if more plant remains were recovered, diversity is unlikely to increase. Although there is possibly undiscovered plant remains (seed/fruit/grain/etc.) diversity in zones B3, B2, B1 and A2, it is clear that B1 and B2 are more diverse than A1 and A2. In contrast, Fig. 4b 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 on its diversity must remain tentative, as the rarefaction analyses suggest there may yet be many undiscovered taxa.

Habitat preferences

A mixture of taxa preferring either wet or dry habitats, and quite a few generalists that thrive in both were present at Kharaneh IV (ESM2, ESM 3). On the basis of this classification the plant remains and taxa density of taxa with different habitat preferences across stratigraphic zones pointed at several trends of changes of the local environment. The density of plant remains classified as ‘dry’ taxa is lowest in zones B3 (the lowest, lower Early Epipalaeolithic, see Table 1) and A1 (the uppermost, upper Middle Epipalaeolithic, see Table 1), while that of plant remains from taxa that prefer wet habitats seems to decline as stratigraphy becomes shallower, with the lowest density of ‘wet’ plant remains in A1 (Fig. 5a). A X^2 test confirmed that the relative proportions of plant remains of taxa with different habitat preferences differs significantly across zones (X^2=711.9, df=8, P<0.0001).

The diversity of wet taxa (Fig. 5b) seems to decline from deeper to shallower stratigraphic zones, with the biggest drop occurring from A2 to A1. Zone A1 also has a low diversity of dry and varied taxa, although these diversities are more variable across zones. An exceptionally high diversity of dry-preferring taxa is present in zone B3, but given the small sample sizes from this area implications of this should be treated with caution, as highlighted by the X^2 test (X^2=4.39, df=8, P=0.82).

Discussion

Local environment and use of the site

The diversity and abundance of taxa can provide some insights into the environmental conditions at Kharaneh IV and how they changed throughout occupation. Continuous records of climatic and environmental change through the Last Glacial Interglacial Transition are lacking for the region east of the Dead Sea, so any insights that can be added to current understanding of local responses to this global climatic transition are useful, particularly from sites that cover thousands of years. The environmental inferences drawn, however, should be treated with caution as they can also be influenced by other factors, such as the selection of plant resources that were brought onto the site and spatial changes in environmental conditions, notwithstanding the limitations posed by the lack of finer taxonomic identifications in several instances.

The deepest stratigraphic zone B3 had the lowest diversity of taxa across all periods but the rarefaction analysis suggests that this may simply be an artefact of the relatively small sample size (Fig. 4); the earliest occupation layers at the site underwent limited excavation during the 2009 and 2010 seasons. At this early stage of occupation, it is also possible that there was lower frequency and/or less intensive use of the site resulting in reduced amounts of plants being collected, moved or stored on site. The ecology of taxa recovered from this zone shows a dominance of taxa such as Chenopodiaceae, *Atriplex* sp., and *Nitraria schoberi,* suggesting a predominantly dry environment. However, the presence of quite a few generalists and some wet taxa (in particular the possible Cyperaceae cores), indicate that conditions were likely not uniformly dry in time and/or space.

Zone B2 includes the most diverse taxonomic assemblage (Fig. 4). The ecology of the taxa recovered in this zone again suggests a varied habitat (Fig. 5) but with less extensively, or intensively, dry conditions compared to Zone B3. In Zone B2 there were a few Cyperaceae, suggesting the presence of standing water during at least one point in the year. The large number of varied taxa in this zone could have tolerated habitat fluctuations and spatial variability in water availability. However, overall the data hint at more local water availability compared to Zone B3. This is consistent with other evidence of more intensive human use of the site during this time, with a higher frequency of floors and occupational surfaces (Maher et al. 2012). Increased site use could, however, also have led to a broader temporal and spatial catchment for plants used on the site.

In Zone B1, taxa diversity was intermediate in comparison with the other zones. Dry species have a higher plant remains density here (Fig. 5a) 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 (Fig. 2), which again adds evidence towards an arid environment. However, it must be noted that heads of this species could contain hundreds of fruits, introducing a potential bias. In contrast, varied habitat species dominate the diversity measures, and the diversity of wet taxa is higher than dry (Fig. 5b), with members of the Cyperaceae family in B1 indicating the presence of standing water at some point during the year within some proximity to the site. Thus, while overall the habitat may have been relatively dry, this was not uniformly so and there may have been relatively more local wet habitats in this phase than during B2.

During Zone A2 a varied habitat seems to have been present. Notably, this zone includes the highest density of varied taxa, accompanied by the highest density of dry taxa (Fig. 5). In contrast to B2 and B1, there are fewer wet than dry taxa and this may possibly suggest that this period of occupation was relatively drier, although precise environmental inferences are difficult to make.

Zone A1 provides information on the final occupation stage at the site. This zone registers the second lowest diversity of taxa and a generally low plant remains and taxa density, which is possibly due to its location close to the surface, which may have undergone more recent deflation. The low density and diversity are consistent with conditions of low productivity and a strong environmental filter (Weiher et al. 1998; Keddy 2010). 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 than wet taxa, their relative proportions are not obviously different from the earlier A2 Zone.

Overall, this analysis of Kharaneh IV provides a general overview of conditions but at relatively low ecological resolution. The mix of dry, varied and wet taxa at all time periods is consistent with Ramsey 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 resource repository the surrounding wetlands provided, which would have in turn allowed them to undertake riskier foraging forays beyond the wetlands. Overall, the archaeobotanical data seem to support the geomorphological results (Jones et al. 2016b) but they do not fully accord with the phytolith data, which suggest relatively wetter conditions in the Middle Epipalaeolithic period (Ramsey et al. 2016). Changes in density and diversity of wet and dry species, from both phytolith and archaeobotanical data, are suggestive of environmental change, but the specificity and the degree of reliability of these inferences is impacted by various factors, including sample sizes and the low taxonomic and, therefore, ecological resolution of the data. Use of these individual proxies should therefore be treated with caution, and highlights a research question that requires further work.

Plant food and diet

Detailed reconstruction of the Epipalaeolithic hunter-gatherer diet is a challenging task due to several recovery, preservation and taphonomic problems that bias in favour of the visibility of the meat component. Nevertheless, as more lines of evidence, including archaeobotanical studies, are being integrated into research programmes, a more complete picture of hunter-gather diet is slowly emerging. At Kharaneh IV the zooarchaeological assemblage (Martin et al. 2010) showed that gazelle was the predominant prey but many other local animals were also hunted, trapped or collected, including larger equids, wild cattle, wild boar, small canids, fox, hare, birds and tortoises. The presence of ground stone tools at Kharaneh IV (Maher et al. 2008, 2009; Ramsey et al. 2016) provide some indirect evidence and hints at some form of plant processing on site. The increased finds of ground-stone tools during this period have been linked with an increasing importance of grass resources (Wilcox 2005; Edwards 2007). However, ground-stone tools can be used for processing of other resources like roots and non-food fibres, not just grains (Dubreuil, 2004; Wollstonecroft, 2009; Hurcombe 2014; Arranz Otaegui et al. 2018a). The archaeobotanical data presented here shed new light to these otherwise invisible practices and, when combined with regional and historical vegetation information, allow us to infer some new aspects of the possible dietary resources accessed by the occupants of Kharaneh IV.

Starch-rich foods other than grasses (for these see below) would have been available from local wetland species, such as the knotweed *Polygonum cf. salicifolium*, or from sedges such as *Scirpus*, whose presence at Kharaneh IV is suggested by phytoliths (Ramsey and Rosen 2016; Ramsey et al. 2016). The available bulbs and nutlets would have been at their highest caloric concentrations during winter 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* (Hillman et al. 1989, 2000). The hunter-gatherer Egyptian site of Kubbaniya offers an archaeological parallel where consumption of these nutlets was confirmed by their presence in human coprolites (Hillman et al. 1989).

Another potential source of food are chenopods, which were present throughout the Kharaneh IV assemblage. It should be noted however, that although they are relatively abundant, each of these plants can produce thousands of fruits. Ethnographic evidence from hunter-gatherer sites elsewhere in the world suggests chenopods are a feasible food source. There are examples of chenopods being used particularly during the autumn and winter months

(Hillman 2000), such as the use of *Suaeda suffruticosa* by the Cahuilla people (Bean and Saubel 1972, 45), along with the use of Mexican fireweed (*Kochia scoparia*), and *Atriplex* sp. (Rogers 1989). The new leaves of *Atriplex* are also edible (Mandaville 2011).

Grass grains were present at Kharaneh IV but there was no evidence of chaff, and consequently potential processing, on site. However, given the presence of a number of small seeded grasses, and a few larger grains, such as (possibly) *Taeniatherum* sp. and wild barley (*Hordeum* sp.), the collection of wild cereals as a means of subsistence was possible. Wild stands of cereals must have existed within a reasonable distance to the site, given the presence of some fairly large grained Gramineae.

Evidence for the potential consumption of fruits and nuts is also limited. The most notable such find in the seed assemblage at Kharaneh IV is *Nitraria schoberi*, offering a glimpse into an additional available food source. There is modern, ethnographic evidence of *Nitraria schoberi*'s use by the Bedouin, who collect these salty, sweet fruits and eat them either raw or processed by boiling them down into a sort of jam (Mandaville 2011). Drying the fruits could have also extended their preservation period, allowing them to be stored for the winter months.

Starchy tissues, such as tubers and bulbs, are another potential food source for the hunter-gatherers (e.g. Pryor et al. 2013; Arranz-Otaegui et al. 2018a), but very few fragments were found in the Kharaneh IV samples. The low numbers of this type of charred tissue, however, can be due to cultural, taphonomic and sampling factors. Plants like vegetables, tubers and other roots can be roasted directly in the fire or the surrounding coals, in which case the whole item or forgotten/discarded fragments may only preserve as unidentifiable residues which are easy to overlook during analysis (Hather 1988; Pryor et al. 2013). These tissues can also be sensitive to water and may disintegrate into small fragments upon contact with water (observed by the lead author at other sites), including during flotation (e.g. Arranz-Otaegui 2017, Arranz-Otaegui et al. 2018a).

Many other food sources are not detectable in archaeobotanical samples because they are never, or rarely, cooked. The likely missing candidates include items such as 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 (Musil 1928; Zohary 1973; Bailey and Danin 1981; Mandaville 2011). Bailey and Danin's (1981) account of the Bedouin plant use in the Sinai and Negev, for example, shows that most of the plants used are ones that can be eaten without cooking, and similarly, Musil (1928) recorded several species that are eaten raw by the Bedouins. Overall, although the list of plant foods at Kharaneh IV is probably incomplete, these results allow us to build up a picture of the resources available to inhabitants of the site.

The Kharaneh IV plant assemblage in the context of the southern Levant

The 2985 identified seeds/fruits/grains/etc. from Kharaneh IV are a substantial addition to the archaeobotanical evidence of Epipalaeolithic life in the southern Levant, and comparisons with other published work highlights the importance of this site in understanding plant use by the people of this period. Other Epipalaeolithic sites (Fig. 1) with published archaeobotanical remains in this region are: 1) Ohalo II, the earliest site of the period dated to 22500-23500 BP (e.g. Snir et al. 2015; Weiss et al. 2004b); 2) Wadi Jilat 6, coeval to Kharaneh IV and dated to 18,503-13,487 cal. BP (Colledge 2001); 3) El-Wad, dated to the Early Natufian period, aprox. 15000-13.500 BP (Caracuta et al. 2016); 4) Shubayqa 1, dated to 14600-14200 BP (Arranz-Otaegui et al. 2018a); 5) Wadi Hammeh 27, dated to the Early Natufian period, 12,800/12,500- 11,250 BP (Colledge 2001); and 6) Hayonim Cave, the Natufian occupation layers of which have been dated to 12,360 (+/-) 160 BP (Hopf and Bar-Yosef 1987).

The sampling and processing of material from Kharaneh IV has produced an order of magnitude more plant remains than most other comparable sites in the region, with only the earlier site of Ohalo II (e.g. Snir et al. 2015; Weiss et al. 2004b) and later site of Shubayqa 1 (Arranz-Otaegui et al. 2018a) producing substantially more plant remains, from distinctly different types of deposits.

The spread of published Epipalaeolithic plant remains in space (Fig. 1) and time means that drawing regional pictures of environmental settings or lifeways from these data alone remains difficult. Wadi Jilat 6 is the nearest site in time and space to Kharaneh IV and yet a quite different range of species was found here. 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* sp., and *Verbascum* sp. (Colledge 2001). However, considering the family level, 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. Despite differences in species, 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, although potentially not in the same form as the wetlands found near to Kharaneh IV given geomorphological differences between the two sites (Garrard and Byrd 2013; Jones et al. 2016b). The similarities and differences in archaeobotanical finds between Kharaneh IV and Wadi Jilat 6, further suggest that the Epipalaeolithic Azraq Basin was a mosaic of ecological habitats (Ramsey and Rosen 2016; Jones et al. 2016a), which reinforces the importance of local resolution in the interpretation of hunter-gatherer sites and practices.

An important aspect in the debate of Epipalaeolithic diet is the use of grasses. Substantial quantities of grasses were present in the Ohalo II assemblage, including more than 2000 wild cereal remains, among which wild emmer (*Triticum dicoccoides*) and wild barley (*Hordeum spontaneum*) (Kislev et al. 1992; Weiss et al. 2004b). These species 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. In contrast, few grasses were found at Kharaneh IV and most other southern Levantine sites, with *Hordeum* sp. being the most ubiquitous (present in all sites but Wadi Jilat 6), although in low numbers, as for example at the site of el-Wad (Caracuta et al. 2016). Beyond Ohalo II, plant processing by-products (chaff) have been found at Wadi Hammeh 27, in very low quantities (3 *Hordeum spontaneum* rachis internodes; Colledge 2001), and at Shubayqa 1 (Arranz-Otaegui et al. 2018a). Arranz-Otaegui et al. (2018b) showed that *Triticum boeoticum* was used, along with other crops, to make bread-like products at Shubayqa 1, but there is not overwhelming evidence of grasses being a widespread major food group for Epipalaeolithic communities across the region compared to other plant types.

There are interesting comparisons to be made with other food types too. *Nitraria schoberi* was found at Ohalo II (Kislev et al. 1992) as well as Kharaneh IV. It seems likely that these small fruits were present in the local food pantry of people using both sites. Cruciferae were common at Kharaneh IV with a particular high concentration in a hearth in Area A (ESM1). This is interesting as Cruciferae were also the second main plant find recovered in very high numbers from the two fireplaces studied at Shubayqa 1 (Arranz-Otaegui et al. 2018a). It has been suggested that most of the Cruciferae found at the studied fireplaces of Shubayqa 1 would have entered the assemblage alongside the wood of the plant to be used as fuel, following complementary wood charcoal data, and only a few taxa could have been used as food. At Kharaneh IV the charcoal study of the hearth has not yet been completed to add to the interpretations but the incorporation of Cruciferae both as food and fuel is possible. In contrast, there is little evidence of tuber or legume use at Kharaneh IV as found at Shubayqa 1 (Arranz-Otaegui et al. 2018a) and el-Wad (Caracuta et al. 2016) respectively. Legumes in particular occur in most of the other sampled sites but in low numbers, similar to Kharaneh IV, and there is no unequivocal evidence for their use as food there. When comparing archaeobotanical results between sites, the picture is one of Epipalaeolithic peoples exploiting their local or near-local environments, which themselves varied in time and space.

Conclusions

This study has presented the first macrobotanical (other than charcoal) results and analysis of the Epipalaeolithic site of Kharaneh IV. Kharaneh IV is an important site in terms of the density and diversity of the archaeobotanical remains, which is unique in the region for that period of the Epiplalaeolithic. Despite the various challenges related to the analysis and interpretation of the Kharaneh IV archaeobotanical material, the data have allowed the delineation of: a) a likely varied use of plants in the local diet, in which grass resources did not appear to be more important compared to other plants on current evidence, and; b) the formulation of hypothesis on fluctuating and eventually drier environmental conditions in the area that may have contributed to the eventual abandonment of the site. Both findings provide focus for future work as more material is processed from the site and more analyses undertaken. Comparison with the coeval, nearby site of Wadi Jilat 6 further supports the emerging picture of an ecological mosaic within the Epipalaeolithic Azraq Basin. Overall, the sparse nature of Epipalaeolithic archaeobotanical data requires cautious interpretation of any apparent patterns, but comparing and contrasting the archaeobotanical results of Kharaneh IV with those from Epipalaolithic sites from the southern Levant has broadened the picture of plant resource use by hunter-gatherers of the period. Ultimately, the study of the Kharaneh IV plant remains has shed new light on, and has added to the corpus of knowledge of hunter-gatherer practices and interactions with their environment.

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List of Figure and Electronic Supplemental Material captions:

Figure 1: Location map of Kharahneh IV (KHIV) within the Azraq Basin (after Jones et al., 2016). Inset shows location of other Epipalaeolithic sites with published archaeobotanical remains (see text for details); Wadi Jilat 6 (WJ6), Shubayqa 1 (SH1), Wadi Hammeh 27 (WH27), Ohalo II (OHII), Hayonim cave (HC), el-Wad (EW).

Figure 2: Relative density of archaeobotanical remains within Stratigraphic Zones of Area B and the change in relative density between zones

Figure 3: Relative density of archaeobotanical remains by taxon within stratigraphic Zones of Area A and the change in relative density from A2 to A1

Figure 4: Rarefaction curves, with standard errors (dashed lines) comparing the taxa richness of each Stratigraphic Zone: (a) the entire range of sample sizes for each zone, and (b) sample sizes from 0 to 50, to highlight patterns at small sample sizes. Zone B3 is shown in black to make it visible given high overlap with other curves

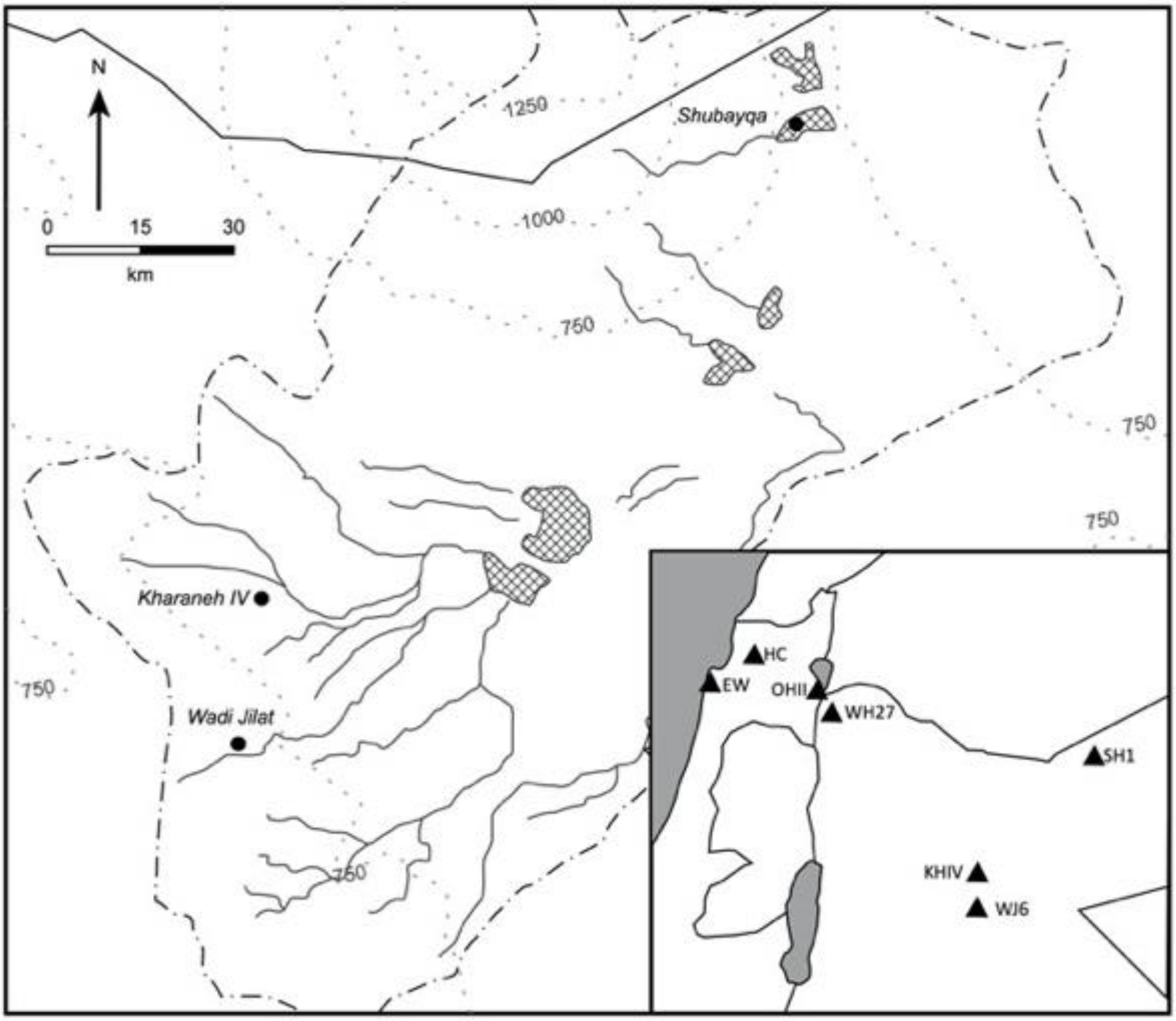
Figure 5: a) Density of archaeobotanical remains (='seed' density) (number of archaeobotanical remains/L) of taxa that prefer wet, dry or varied (generalists) habitats by stratigraphic zone and (b) Density of taxa (number of taxa/L), a measure of diversity, that prefer wet, dry or varied (generalists) habitats by stratigraphic zone. Zone B3 is the deepest (oldest) and Zone A1 is the uppermost (youngest). Habitat generalisations are given in ESM 2.

ESM 1: List of archaeobotanical items in each sample and sample information for Areas A and B

ESM 2: Archaeobotanical data summaries

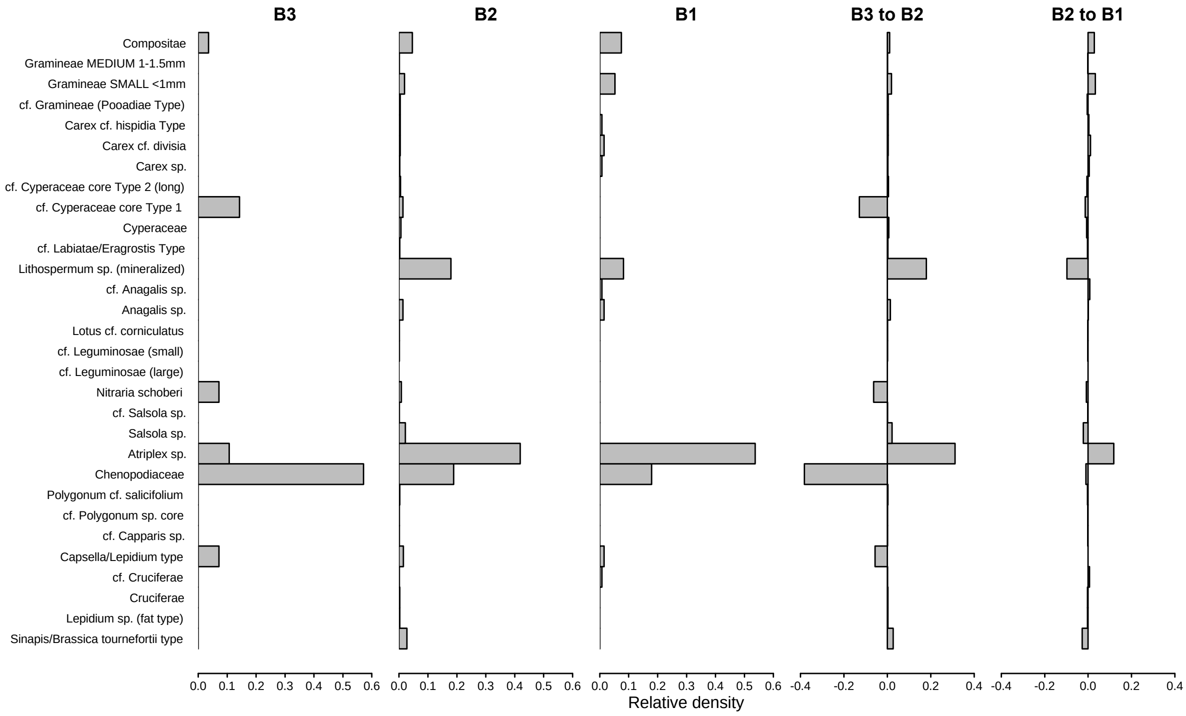
ESM 3: Kharaneh IV major archaeobotanical finds: detailed catalogue

Figure 1



N
0
15
30
km
1250
1000
750
750
750
750
750
750
Shubayqa
Kharaneh IV
Wadi Jilat
HC
EW
OHII
WH27
SH1
KHIV
WJ6

Figure 2



B3
B2
B1
B3 to B2
B2 to B1
Compositae
Gramineae MEDIUM 1-1.5mm
Gramineae SMALL <1mm
cf. Gramineae (Pooadiae Type)
Carex cf. hispidia Type
Carex cf. divisia
Carex sp.
cf. Cyperaceae core Type 2 (long)
cf. Cyperaceae core Type 1
Cyperaceae
cf. Labiatae/Eragrostis Type
Lithospermum sp. (mineralized)
cf. Anagalis sp.
Anagalis sp.
Lotus cf. corniculatus
cf. Leguminosae (small)
cf. Leguminosae (large)
Nitraria schoberi
cf. Salsola sp.
Salsola sp.
Atriplex sp.
Chenopodiaceae
Polygonum cf. salicifolium
cf. Polygonum sp. core
cf. Capparis sp.
Capsella/Lepidium type
cf. Cruciferae
Cruciferae
Lepidium sp. (fat type)
Sinapis/Brassica tournefortii type
0.0 0.1 0.2 0.3 0.4 0.5 0.6
-0.4 -0.2 0.0 0.2 0.4
Relative density

Figure 3

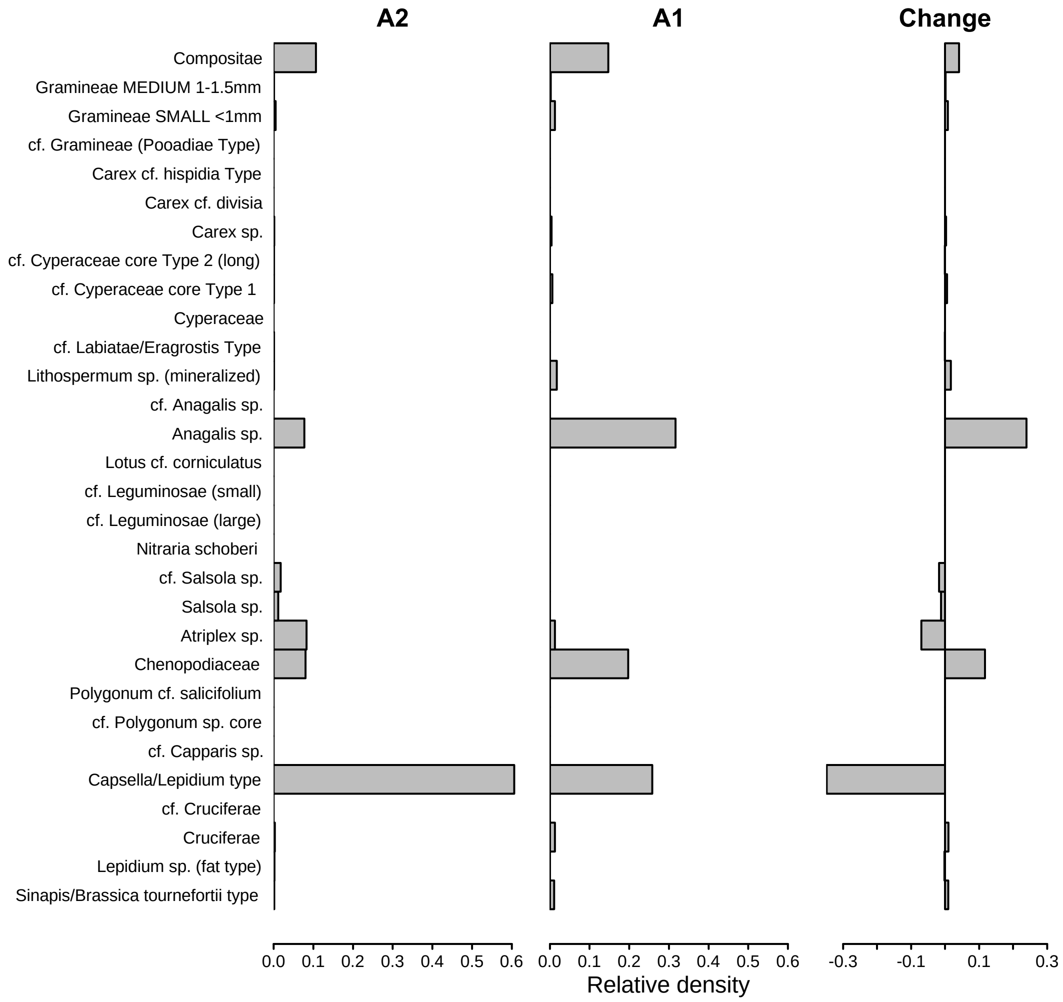

A2
A1
Change
Compositae
Gramineae MEDIUM 1-1.5mm
Gramineae SMALL <1mm
cf. Gramineae (Pooadiae Type)
Carex cf. hispidia Type
Carex cf. divisia
Carex sp.
cf. Cyperaceae core Type 2 (long)
cf. Cyperaceae core Type 1
Cyperaceae
cf. Labiatae/Eragrostis Type
Lithospermum sp. (mineralized)
cf. Anagalis sp.
Anagalis sp.
Lotus cf. corniculatus
cf. Leguminosae (small)
cf. Leguminosae (large)
Nitraria schoberi
cf. Salsola sp.
Salsola sp.
Atriplex sp.
Chenopodiaceae
Polygonum cf. salicifolium
cf. Polygonum sp. core
cf. Capparis sp.
Capsella/Lepidium type
cf. Cruciferae
Cruciferae
Lepidium sp. (fat type)
Sinapis/Brassica tournefortii type
0.0 0.1 0.2 0.3 0.4 0.5 0.6
0.0 0.1 0.2 0.3 0.4 0.5 0.6
-0.3 -0.1 0.1 0.3
Relative density

Figure 4

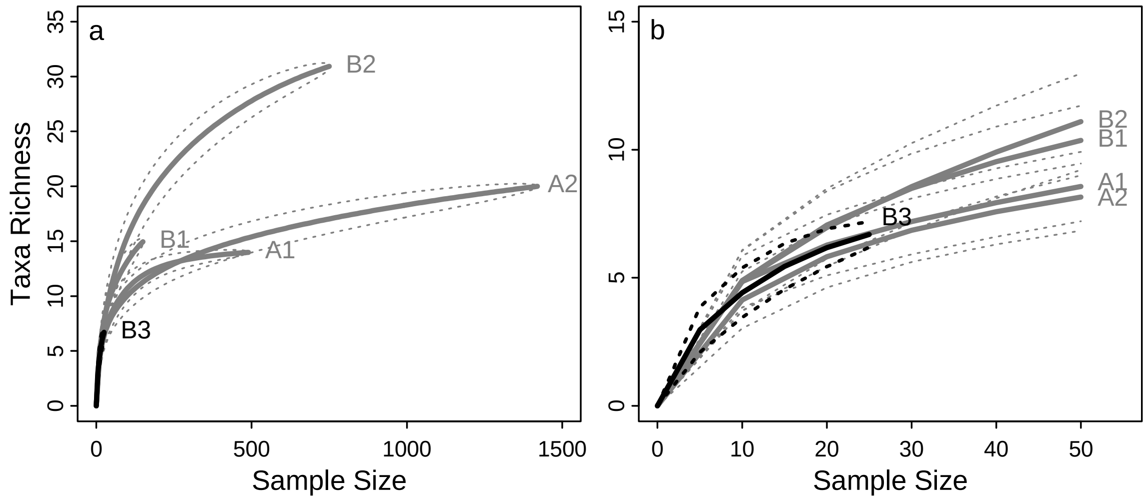


Figure 5