Wedded to Wetlands: Exploring Late Pleistocene Plant-Use in the Eastern Levant

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Abstract

The mosaic ecology of the Late Pleistocene Levant has been referred to by many authors investigating Epipaleolithic use of wild cereals as a prelude to cultivation, but it has rarely been the focus of studies investigating hunter-gatherer adaptations and diverse wild plant collection strategies. Partly, this was due to poor preservation of macro-botanical remains at Epipaleolithic sites with the exception of Ohalo II. Our analyses of 100 phytolith samples from four sites in the eastern Levant, compared with phytoliths from Ohalo II, reveal evidence for how foragers used the unique *local* ecological opportunities in these regions. Abundant phytoliths from reeds and sedges indicate the critical importance of wetlands in hunter-gatherer subsistence strategies. Wild cereals and grasses point to steppe and parkland exploitation, and woody plants indicate use of woodlands. From the Late Upper Paleolithic through the Middle Epipaleolithic our evidence

indicates that wetland, steppe/parkland and woodland zones formed an integrated resilient system of plant-use, with wetlands providing an especially important focal point. We also found that different wetland types and their productivity relative to the surrounding landscape have a clear impact on hunter-gatherer adaptation and plant-use. Focusing subsistence and settlement around the reliable wetland zones provided a dependable natural food-storage repository and allowed greater risk-taking strategies for other types of plant and animal exploitation beyond the wetland zones.

Key words: phytoliths, sustainable adaptations, wetland plant-use, hunter-gatherers, Late Pleistocene, Levant

1. Introduction

The distribution and composition of ecological opportunities had a tremendous impact on Late Upper Paleolithic to Middle Epipaleolithic (ca. 28-14.4 ka cal. BP) (Maher et al., 2012b) (also referred to as ‘Late Pleistocene’) hunter-gatherers, influencing the ways they chose to adapt to the changing Levantine landscape during the Last Glacial Maximum (LGM) (23-19 ka cal. BP) (Robinson et al., 2006). Patterns of settlement and subsistence reflect regional resource opportunities and challenges; decisions were constrained by the types, abundance and availability of critical resources, particularly sessile resources like plants and water (Binford, 1980; Butzer, 1982; Jochim, 1976; Kelly, 1995; Winterhalder, 2001). While the mosaic ecology of the Late Pleistocene Levant is referred to by many authors investigating the early use of wild cereals as a prelude to cultivation (Bar-Yosef, 1996; Henry, 1989; McCorriston and Hole, 1991), it has rarely been the focus of studies investigating hunter-gatherer adaptations and diverse wild

plant collection strategies (Rosen, 2011). Research concerning people-plant interactions in the Levant during this period is undermined by two factors. Firstly, most research is based on data solely from contexts in the Western Levant, more specifically from a limited number of environments, largely coastal and Mediterranean woodlands. Secondly, poor preservation of macrobotanical remains from site contexts has resulted in researchers being unable to find direct evidence of ancient plant use except in situations of exceptional preservation, such as the site of Ohalo II (23 ka cal. BP).

Our paper seeks to redress this imbalance and develop a broader understanding of Late Upper Paleolithic-Middle Epipaleolithic (pre-Natufian) (ca. 28-14.5 ka cal. BP) plant-use and adaptation by investigating 100 phytolith samples from five sites located in a variety of environments. Significantly, we use phytolith evidence from the site of Ohalo II (Ramsey, 2015b) as a baseline to inform our interpretation of four sites in the Eastern Levant; Kharaneh IV (Ramsey, 2015a), Tor Sageer, Yutit al-Hasa (Ramsey, 2015c) and Wadi Madamagh (Ramsey, 2015d) (Figure 1). Our investigation reveals new evidence for how foragers used the unique *local* ecological opportunities in these regions to develop integrated and resilient adaptations, focusing subsistence and settlement around the reliable wetland zones.

2. Late Pleistocene Plant-Use in the Eastern Levant

2.1 Late Pleistocene Chronology in the Eastern Levant

The Late Pleistocene chronology has been widely discussed in the Levantine literature (see Bar-Yosef, 1980, 1981; Belfer-Cohen and Goring-Morris, 2014; Garrard and Byrd, 2013; Goring-Morris, 1995; Goring-Morris et al., 2009; Henry, 1988, 1989, 1995). Following Belfer-Cohen and Goring-Morris (2014) and Maher et al. (2012b) the periods can be divided into the

Late Upper Paleolithic (ca. 30-24 ka cal. BP), Early Epipaleolithic (ca. 24-17.5 ka cal. BP) (start date following Belfer-Cohen and Goring-Morris (2014)), Middle Epipaleolithic (ca. 17.5-14.5 ka cal. BP) and Late Epipaleolithic (ca. 14.5-11.5 ka cal. BP) phases.

Within these broad phases there are a complex variety of tool industries, categorized by stylistic trends in the chipped stone artifacts, particularly microlithic components. In general, there is a stylistic shift from narrow non-geometric microliths, to wider more geometric forms through time. However, regional typologies continue to be refined and developed. The sites in this study generally fall within the spectrum of two largely contemporary lithic industries, the Kebaran and Nebekian. Ohalo II has been described as an Early Kebaran site (see Nadel, 1990; Nadel, 2003) (but has also been described as a Late Ahmarian/Masraqa site by Kadowaki (2013)), while Kharaneh IV (Maher et al., 2007; Muheisen, 1988) features a Kebaran and Geometric Kebaran occupation (Maher et al., 2007; Muheisen, 1988). Tor Sageer (Olszewski, in press), Yutit al-Hasa (Olszewski and al-Nahar, 2010) and Wadi Madamagh (Kirkbride, 1958; Olszewski and al-Nahar, 2011; Schyle and Uerpmann, 1988) fall within the spectrum of the Nebekian industry, although comparable pre-Nebekian assemblages underlie the Nebekian components at Tor Sageer and Wadi Madamagh (Olszewski, in press) (Figure 3).

There has been much debate amongst Levantine prehistorians working during the Late Pleistocene regarding the classification and interpretation of lithic industries (Bar-Yosef, 1980, 1981; Belfer-Cohen and Goring-Morris, 2003, 2014; Byrd, 1994b; Garrard, 1998; Garrard and Byrd, 2013; Goring-Morris, 1995; Henry, 1988, 1989, 1995; Maher et al., 2011; Olszewski, 2001, 2003, 2006). Following Richter et al. (2011:102), we view these lithic industries as ‘traditions’ in the broadest possible sense, but for the sake of clarity, we avoid using the tool industries as synonyms for the general phases (ie. Late Upper Paleolithic, Early-Middle

Epipaleolithic). While, we acknowledge these lithic toolkits may represent different cultural groups, which may have some bearing on their exploitation of the environment, in this paper we do not interrogate the phytolith data to that end. Instead, we employ a broad landscape level approach that emphasizes the role of each sites' unique ecological setting in the development of Late Pleistocene hunter-gatherer plant-use and adaptation.

2.1 Climate and Vegetation Change in the Late Pleistocene

Hunter-gatherer adaptations are structured by the types, abundance and availability of critical resources (Binford, 1980; Butzer, 1982; Jochim, 1976; Kelly, 1995; Winterhalder, 2001). The climate and environment during the Late Upper Paleolithic-Middle Epipaleolithic is important for modeling and understanding patterns of plant-use in the Eastern Levant. Spanning the Last Glacial Maximum (LGM) to the Pleistocene – Holocene transition, the Late-Upper Paleolithic-Epipaleolithic was a period of acute and abrupt climate change (see Maher et al., 2011).. Pollen cores from Lake Ghab and Lake Hula (Baruch and Bottema, 1991; Cappers et al., 1998; Rossignol-Strick, 1995; Yasuda et al., 2000), speleothems from Soreq Cave (Bar-Matthews et al., 1997; Bar-Matthews and Ayalon, 2003), and the paleohydrology and limnological history (Bartov et al., 2002; Black et al., 2011; Hazan et al., 2005; Torfstein et al., 2013) inform regional paleoenvironmental reconstructions. While specialists disagree over the exact timings and nature of late Pleistocene climate change, for example, how seasonal precipitation was distributed (Enzel et al., 2008; Orland et al., 2012), most agree that the LGM (ca. 23,000-19,000 cal. BP) was generally cold and dry. There were a fluctuating series of interstadials including the post-LGM warming of the Bølling-Allerød (BA) (ca. 15,000-13,000 cal. BP). This climatic amelioration ended with the Younger Dryas (YD) glacial reversal (ca. 13,000-11,500 cal. BP).

A number of researchers have used the general trends in the proxy data to estimate the distribution of vegetation under the changing climatic conditions (Baruch and Bottema, 1999; Langgut et al., 2011; Moore et al., 2000; van Zeist and Bottema, 1991). Warm wet conditions associated with interstadial periods are linked to the expansion of food-rich Mediterranean forest and parkland, and the retreat of xeric steppe vegetation. Likewise, cold dry conditions associated with the glacial periods are linked with steppe expansion, and the retreat of parkland and woodland. Although the above description is a constructive generalization, some researchers have noted that change did not occur uniformly throughout the region (Robinson et al., 2006). This emphasizes the importance of site specific environmental data, particularly the structure and availability of sessile resources, such as plants and water.

2.2 Evidence of Plant-Use in the Eastern Levant

Direct evidence of Late Pleistocene plant-use in the Levant is limited due to poor macrobotanical preservation. However, exceptional cases of macrobotanical preservation including Ohalo II in Israel (see Kislev et al., 1992; Nadel et al., 1994; Snir et al., 2015; Weiss et al., 2008) and by analogy Wadi Kubbaniya on the Upper Nile in Egypt (Hillman et al., 1989), provide evidence for the use of a highly diverse selection of plant-resources. Yet most sites simply do not yield macrobotanical remains, and in the Eastern Levant macrobotanical evidence dating to the Late Pleistocene is often fragmentary (Colledge, 1991, 2001). As such, researchers have sought other less direct methods to interpret Late Pleistocene plant-use in the region such as ground-stone tools.

Ground-stone tools increase in frequency through the Epipaleolithic (Wright, 1991, 1994). This has led scholars to suggest wild cereal and grass resources were an increasingly

important component of the Epipaleolithic diet (Edwards, 2007; McCorriston and Hole, 1991; Wilcox, 2005). However, interpreting ground stone function is not easy as ground stone tools may be used for a variety of plant-processing purposes, including root resource for food (Dubreuil and Plisson, 2010; Wollstonecroft, 2009; Wollstonecroft et al., 2008) or non-food related fiber processing (Hurcombe, 2014).

Microbotanical residue analysis is an effective method for the extrapolation of ground stone function. Starch residue analysis of ground stone from Ohalo II, has provided evidence for the processing of wild barley (*Hordeum* sp.), wheat (*Triticum* sp.) and oats (*Avena* sp.) (Nadel et al., 2012; Piperno et al., 2004). The identification of cellulose and the near-absence of protein on ground stone tools at the site of Wadi Kubbania, suggested that wetland roots and tubers, rather than wild cereals and grasses were most likely being processed (Hillman et al., 1989). This means that Late Pleistocene hunter-gatherers employed food processing to improve the nutrition and edibility of a variety of ‘low-ranked’ resources (Smith, 2012; Wollstonecroft, 2011; Zeder, 2012), in addition to wild cereals and grasses. Moreover, it implies that hunter-gatherers in the Levant employed a diverse plant-resource set and novel processing strategies to capitalize on their local plant-resource opportunities (Asouti and Fuller, 2012; Hillman, 1996; Savard et al., 2006; Wright, 1991, 1994).

Phytolith analyses from Late Epipaleolithic sites in the Western Levant have also provided direct evidence of local and flexible strategies of plant-use. The evidence demonstrates that Late Epipaleolithic hunter-gatherers exploited the rich resource mosaics available to them by integrating the use of wetland, woodland and steppe/parkland resources, and opportunistically shifted their exploitation emphasis towards wetland resources in response to increasing aridity (Portillo et al., 2010; Rosen, 2010, 2011, 2012a, b, c, 2013; Rosen, 1993; Rosen, 2007).

2.3 Focused on the Wetland: An Integrated and Resilient System of Plant-Use

In contrast to the favorable micro-mosaic ecology of the Western Levant (Bar-Yosef, 1998), the Eastern Levant was an arid and phytogeographically marginal environment, except where the Pleistocene lakes, rivers and spring-fed wetlands punctuated the steppe and parkland expanse. Given the importance of water in arid regions, Byrd (1994a) predicted that settlement in the Eastern Levant was organized around periodic wetlands. Some of these wetlands were more permanent than periodic, and in support of Byrd's (1994) assessment, served as a central base for Late Pleistocene peoples (Cordova et al., 2013; Jones and Richter, 2011; Olszewski, 2000; Olszewski and Coinman, 1998; Richter et al., 2013; Rosen, 2012a, 2013).

Building on these works, wetland exploitation is a promising way to understand Late Pleistocene hunter-gatherer resilience within the context of local resource opportunities and challenges. Wetlands can provide reliable perennially available plant resources, particularly seeds and roots of monocotyledons, with the additional benefit of an increase in nutrient quality of plant roots during dry, low-growth periods (Wrangham et al., 2009:632). However, wetlands are not all lush plant-food producing *oases* or '*Edens*' (Childe, 1952). Indeed, swamps, marshes, bogs, fens, wet meadows and shallow water littoral zones are all broadly defined as 'wetlands', but each have their own unique characteristics (Keddy, 2000:18), determined mainly by the transition zones between terrestrial habitat and aquatic features.

Phytolittoral zones typical of marshes and the edges of some shallow water environments are identified as the most productive wetland areas (Keddy, 2000:85) (Figure 2). The plants that thrive in this phytolittoral zone include some sedge varieties (Cyperaceae), cattail (*Typha* sp.) and reed grass (*Phragmites* sp.). These plant varieties are of great economic and subsistence

value to humans for the fauna they attract and their own nutritional and favorable ecological qualities. However, compared to other plant resource types, the roots of these aquatic species provide the lowest nutritional return rate at ca. 182 kcal/h, compared to terrestrial roots (ca. 2,267 kcal/h), nuts and acorns (ca. 832 kcal/h) and small seeds (ca. 364 kcal/h) (Bettinger and Wohlgemuth, 2011 and references therein) . Consequently, wetland plant foods might be shown to provide what people need (reliable, but low calories and water), rather than what people want (high calories, variability and flavor).

Wetland environments characterized by an expansive phytolittoral zone provide a large-scale concentration of reliable plant resources. Marshes and lakes tend to offer such a coarse-grained mosaic of resource opportunities, whereas rivers, or other wetland environments where the phytolittoral zone is narrowly circumscribed, do not allow for the large-scale concentration of plant resources. However, wetlands characterized by narrowly circumscribed phytolittoral zones have other favorable characteristics, offering a mix of phytolittoral and riparian elements, a micro-mosaic environment with small-scale plant and animal resource opportunities. Riparian environments, while not as rich in reliable plant resource opportunities, include a greater proportion of woody trees and shrubs, and serve as important corridors for the movement of larger wildlife (Kocher and Harris, 2007).

The character and structure of the wetland is critical to understanding how regional adaptations developed. For example, the deep lakes contained fish, riparian areas funneled game, and shallow lakes and marshes offered a variety of plant foods. These resource opportunities must then be compared to the character and structure of the resources offered in the broader surrounding landscape, for instance, whether acorns, large game and/or grass seeds were near or far away. Even in the driest areas of the Levantine steppe there was a diversity of edible plant

species. In the Azraq Basin up to 70% of the vegetation was edible, but was only available in very low densities (Hillman, 1996).

Despite lacking the food-rich mosaic of the Western Levantine Mediterranean forest, in the Eastern Levant wetland systems may have been an equivalent focus for Late Pleistocene hunter-gatherer resource exploitation (Olszewski and Coinman, 1998). Yet diverse wetland forms, and their productivity relative to the surrounding steppe/parkland, would have largely determined the ecological opportunities on offer in the Eastern Levant during the late Pleistocene. Accordingly, we expect foraging decisions were shaped not only according to what resources the wetlands offered, but also in respect to what was, or was not available in the surrounding steppe/parkland and woodland zone (*sensu* Madsen and Kelly, 2008).

3. Towards an Understanding of Plant Exploitation Strategies

This investigation capitalizes on the unique macrobotanical preservation of Ohalo II by using the phytolith evidence from this site as a relative benchmark for the sites in the Eastern Levant, which do not benefit from good macrobotanical preservation. The extensive macrobotanical assemblage at Ohalo II has been studied by a number of specialists in peer reviewed publications (Kislev et al., 1992; Nadel et al., 2004; Snir et al., 2015; Weiss et al., 2004a; Weiss et al., 2008) and unpublished doctoral dissertations (Simchoni, 1998; Weiss, 2002).

The macrobotanical assemblage at the site is highly diverse and includes wild barley, wild emmer wheat, a significantly large number of small-grained wild grass seeds, acorns (Tabor oak), and a variety of fruits, berries and nuts (Christ's thorn, wild fig, wild grape, almond, pistachio, and wild olive) (Weiss et al., 2004a; Weiss et al., 2004b). Wetland resources were also

a component of the diet, as evidenced by the presence of sedge nutlets (*Scirpus litoralis*, and Cyperaceae cf.) and pond weed nutlets (*Potamogeton* sp.) (Weiss, 2002). The remains are representative of a mosaic habitat, which included a local saline microenvironment, a nearby lakeshore and a Mediterranean open park-like forest (Nadel et al., 2004), likely located further from the site (Nadel et al., 2006b).

Within the context of the previous macrobotanical publications from Ohalo II (Kislev et al., 1992; Nadel et al., 2004; Snir et al., 2015; Weiss et al., 2004a; Weiss et al., 2008), the phytolith evidence from Ohalo II together with the previously published macrobotanical evidence, provides a clearer picture of the explanatory strengths and limitations of the each type of data set, providing critical insights into what the phytolith identification categories may represent in the absence of robust macrobotanical data sets. In this paper, we employ the phytoliths from Ohalo II as a rough benchmark, however a detailed comparative study of the macrobotanical and phytolith data sets at Ohalo II is in preparation.

Our paper is guided by the following questions: Firstly, is there direct botanical evidence to suggest that wetland plant resources were a focal point for Late Pleistocene exploitation in the Eastern Levant? Secondly, do hunter-gatherers in coarse-grained (ie. marshes, lakes) and fine-grained (ie. stream-bank riparian) wetlands exhibit different adaptations (Winterhalder, 1981), particularly in their use of wetland plant resources? Lastly, by employing phytolith indicators of ecozone-type (reeds and sedges indicate wetlands, wild grasses and cereals indicate steppe and parkland, and woody plants indicate woodlands), can we reveal broad evidence for how foragers used the unique *local* ecological opportunities in these regions?

4. Sites, Samples and Methods

4.1 Sites and Samples

To address our research questions we conducted phytolith analyses on 100 sediment samples from five sites, Ohalo II in the Western Levant, and four sites from the Eastern Levant, Kharaneh IV, Tor Sageer, Yutil al-Hasa, and Wadi Madamagh. Sediment samples have been taken from a variety of onsite contexts and provide a general picture of plant-use during the periods sampled. In this paper, we take a broad landscape level approach, exploring our phytolith data comparatively at the site level, rather than context specific trends. More detailed site-specific analyses are forthcoming. These sites are located in a variety of environments in proximity to a range of wetlands (Table 1) and collectively span the entire Late Upper Paleolithic-Middle Epipaleolithic (Figure 3), providing a broad picture of hunter-gatherer plant-use.

Site	Location	Environment Zone	Wetland Form	Sediment Samples
Ohalo II	Israel, Lake Kinneret	Open Parkland	Lake	28
Kharaneh IV	Jordan, Azraq Basin	Semi-Arid Steppe/Parkland	Marsh	34
Tor Sageer	Jordan, Wadi al-Hasa	Semi-Arid Steppe	Riparian Wetland	16
Yutil al-Hasa	Jordan, Wadi al-Hasa	Semi-Arid Steppe	Riparian Wetland	11
Wadi Madamagh	Jordan, Wadi Musa region	Mediterranean Forest	Unidentified Wetland	11
Total:				100

Table 1: Summary of site locations, environment descriptions and number of samples.

4.1.1 Ohalo II

Ohalo II is a multi-component Early Epipaleolithic (Early Kebaran or Late Ahmarian/Masraquan) (23 ka cal. BP) site (Nadel et al., 1995) situated on the shore of Lake Kinneret (Sea of Galilee), Israel, in an open parkland setting (Kislev and Simchoni, 2002; Nadel,

2004). The site has an area of more than 2,000 m² (Weiss et al., 2004a). Excavations uncovered the *in situ* remains of six hut structures, several open-air hearth concentrations, a dumping zone, a pit, a stone installation and a burial. The site also contains a rich lithic and faunal assemblage, bone tools, wooden objects and ground stone technology (Bar-Yosef, 2014; Nadel, 2003, 2004; Nadel et al., 1994; Nadel et al., 2006a; Nadel et al., 2012; Simmons and Nadel, 1998). The repeated use of Ohalo II in a consistent and organized pattern lead the investigators to conclude that the site represents the remains of a camp visited several times by the same group (Nadel et al., 1995). Indeed, the floral and faunal remains suggest that there may have been year round occupation at the camp (Kislev et al., 1992; Snir et al., 2015; Weiss et al., 2008).

The site is unique due to its exceptional organic preservation that was caused by two related events: charring by fire before the site was abandoned, followed by inundation by rising water levels and lake sediments (Weiss et al., 2011). A total of 28 sediment samples were analyzed for this study (Table 1). The samples were taken from a variety of onsite contexts, including hearths, dumps and huts. Early recognition of the significance of the site facilitated a thorough sediment-sampling program (Nadel et al., 2012). The samples examined for phytoliths were collected during the summer of 2012 from stored bulk sediments (varying volumes, tablespoon to liters) and 1m x 1m sediment blocks that were exhumed from the site hut deposits. These intact site sediments provided the opportunity to take pin-point samples from some of the most informative contexts.

4.1.2 *Kharaneh IV*

Kharaneh IV is a multi-component Early to Middle Epipaleolithic (19.9-18.6 ka cal. BP) site in the Azraq Basin, Jordan (Richter et al., 2013). It is one of several large Early-Middle Epipaleolithic aggregation sites in the region (Garrard and Byrd, 1992; Richter et al., 2013). The

site was situated on the periphery of a large marsh, surrounded by semi-arid steppe/parkland (Garrard et al., 1994; Garrard et al., 1987; see Hunt in Garrard and Byrd, 2013; Jones and Richter, 2011; Montague et al., 1988). Today, the Azraq wetland is fed by several springs, which are filled by surface runoff and groundwater (Jones and Richter, 2011). A low discharge-to-replenishment ratio means the springs provide a secure supply of water, even under arid conditions (Jones and Richter, 2011; Macumber, 2001). Consequently, in the past, the wetland would have been a reliable resource rich environment *relative* to the surrounding semi-arid steppe/parkland (see Hillman et al., 1989), particularly during periods of greater aridity. This characteristic of the Azraq Basin has attracted human groups to the region since the Lower Paleolithic (Copeland and Hours, 1989; Cordova et al., 2013; Rollefson, 1983; Rollefson et al., 1997).

Originally excavated by M. Muheisen in the 1980's (Muheisen, 1988; Muheisen and Rollefson, 1985; Muheisen and Wada, 1995), Muheisen's work defined the site's stratigraphy and main features, including the rare subfloor burial. Kharaneh IV has an area of 21,000 m² and a depth of ca. 1.5 m in depth. To account for the size and density of the cultural material, Kharaneh IV was originally interpreted as being repeatedly revisited over the long-term course of ca. 3,000-5,000 years. However, new radiocarbon evidence demonstrates that the site was occupied during the shorter time frame of 1,225 years (Richter et al., 2013). This suggests that the site was visited by larger numbers of people than previously thought. These inhabitants likely resided at the site for long periods of time (Richter et al., 2013), on a multi-seasonal or possibly year-round basis (Jones, 2012). Kharaneh IV also features the earliest documented hut structures in Jordan (Maher, 2011; Maher et al., 2012a), a subfloor burial, worked bone objects, a ground stone assemblage and marine-shell beads (Muheisen, 1988; Muheisen and Rollefson, 1985;

Richter et al., 2011; Richter et al., 2013). These material remains provide evidence of increasing sedentism, the use of complex trade networks, sophisticated food processing, personal adornment practices and possibly ritual behavior.

The Early Epipaleolithic occupation (Kebaran) (Area B) covers an area that is approximately 44.5 m² and is over 1.5 m deep (Maher et al., 2009; Maher et al., 2010). However, a sounding (Area F) located north of Area B demonstrated that the Early Epipaleolithic occupation of the site is even greater than previously thought (Maher et al., 2010). The deposits in Area B are complex, and characterized by several overlapping and superimposed occupational surfaces, two hut structures, and a number of hearths and ash pits. The occupation surfaces are at times thin and ephemeral (ca. only 2-3 cm thick). However, the remains are largely *in situ* and continuous, with a high density of artifacts (including several small caches of blades and bladelets), faunal remains and charcoal (Maher et al., 2009; Maher et al., 2010; Martin et al., 2010).

The Middle Epipaleolithic occupation (Geometric Kebaran) (Area A) is approximately 30 m² in area and between 40-45 cm deep (Maher et al., 2009). This area includes several occupation surfaces, two hearth deposits and a series of dark brown sediment deposits that are interpreted to be post-holes. These remains provide evidence of repeated cooking events and the construction of ephemeral structures, thought to be cooking structures or drying racks (Maher et al., 2010).

A total of 34 sediment samples were analyzed for this study (Table 1). The samples were taken from a variety of onsite contexts, including occupation surfaces and features (hearths, dumps and post-holes). Excavations were conducted on a 1 x 1 m grid. However, these squares were further divided into 50 x 50 cm quads when finer controls were needed. The site was

excavated by natural and cultural layers, which were further divided into 5-10 cm arbitrary spits. All of the excavated sediment was subject to flotation or were stored for micro-artifacts, micro-fauna, micromorphology, and sediment analysis (Maher et al., 2010). The phytolith samples for this analysis were collected from the sediment samples taken during the 2008, 2009 and 2010 excavation seasons.

4.1.3 The Wadi al-Hasa: Tor Sageer and Yutil al-Hasa

The Late Upper Paleolithic and Early Epipaleolithic site of Tor Sageer (ca. 27,200-26,580 cal. BP; ca. 24,600-24,150 cal. BP) and Early Epipaleolithic site of Yutil al-Hasa (ca. 25,300-22,400 cal. BP) are located in the Wadi al-Hasa, west-central Jordan (Eastern Levant) (for more details see Olszewski and al-Nahar, submitted for review). The Wadi al-Hasa has been the focus of several archaeological surveys since the late 1970s (Clark et al., 1992b; Clark et al., 1994; MacDonald, 1988; MacDonald et al., 1980; MacDonald et al., 1983; MacDonald et al., 1982). This arid steppe region is of considerable archaeological interest because it is thought to have been the site of a large Pleistocene lake/marsh (70-20 kyr), and a foci of late Pleistocene human activity (Clark, 1984; Clark et al., 1992a; Olszewski and Coinman, 1998; Schuldenrein and Clark, 1994; Schuldenrein and Clark, 2001, 2003). Unsurprisingly, the majority of Late Upper Paleolithic and Epipaleolithic sites in the region are situated in direct proximity to the ancient wetland (Olszewski and Coinman, 1998). However, a recent reinterpretation of the Wadi al-Hasa Pleistocene ‘lake/marsh’ deposits suggests this was actually a stream riparian wetland environment, fed by fresh running water from a precipitation-dominated spring-system (Winer, 2010). This has major implications for our understanding of human adaptation and plant-use in this otherwise steppic region.

Tor Sageer is a small rock shelter occupation, with an area of approximately 24 m², situated 17 m above the modern wadi floor. The site is located on a tributary, approximately 3 km upstream from the Wadi al-Hasa, and has ready access to the Kerak Plateau, immediately north of the Wadi al-Hasa (Olszewski, in press). Excavation was done in arbitrary 5 cm levels. The archaeological assemblage notably includes the distal portion of a carved bone projectile (Kennerty, 2010), a diverse lithic assemblage that includes four woodworking adzes (tentatively proposed based on their form), as well as, ochre and several hearths. The archaeological deposits are approximately 85 cm thick. The uppermost layer (Stratum I) is Early Epipaleolithic (Nebekian), and post-dates ca. 24,631-24,151 cal. BP, as indicated by a radiocarbon date taken from the top of Stratum II. The lower strata II, III and V are all Late Upper Paleolithic and date to ca. 27,216-24,295 cal. BP.

Preliminary pollen analysis of Stratum I indicates riparian elements within an otherwise steppic environmental context. Previous phytolith analysis by A. Rosen on four samples supports this interpretation. Rosen identified panicoid (C₄) and pooid (C₃) grass sub-families as well as some wild grass inflorescences or glumes. Many dicot wood phytoliths were recovered. Sedge and reed phytolith types were also identified (Olszewski, 2003; Olszewski et al., 1998a). In this present study, we analyzed a total of 16 sediment samples from Tor Sageer (Table 1). The samples were taken from a variety of onsite contexts, including features and general site sediments. Phytolith samples were taken at the top of each arbitrary 5 cm level and from archaeological features.

Yutil al-Hasa is a multi-component site with at least one rock shelter on the main Wadi al-Hasa channel. The site is situated in a natural constriction of the drainage, approximately 10 m above the wadi floor, and faces out onto what may have been some kind of wetland setting,

serving to attract and contain the movement of game (Olszewski and Coinman, 1998). Intensive excavation at the site has revealed Late Upper Paleolithic, Early Epipaleolithic and Late Epipaleolithic deposits (Clark et al., 1988; Coinman et al., 1999; Olszewski et al., 1990; Olszewski et al., 1998b; Olszewski et al., 1994). However, only the Early Epipaleolithic Nebekian deposits found in Area C of the rock shelter (dated to between 25,300 to 22,380 cal. BP) were sampled for this research. This context (area C and F) covered approximately 90m². A total of 11 sediment samples from Yutil al-Hasa were analyzed for this study (Table 1). Phytolith samples were taken from every natural level beginning with level 2.

4.1.4 Wadi Madamagh

Wadi Madamagh is a 50 m² rock shelter located in the Wadi Musa region, north of Petra in Jordan. It dates to the Late Upper Paleolithic-Early Epipaleolithic transition (ca. 25,300-22,800 cal. BP). During this period, the region was characterized by Mediterranean woodland. This paleoenvironmental interpretation is based on a remnant oak forest, today in close proximity to the site (Cordova, 2007).

Archaeological evidence indicates that Wadi Madamagh was repeatedly occupied, likely on a seasonal basis. The archaeological remains can be divided into two strata based on the stratigraphy and tool typology (Olszewski and al-Nahar, 2011; Schyle and Uerpmann, 1988). The lower layers date to the Late Upper Paleolithic, while the upper layers date to the Early Epipaleolithic. Consequently, Wadi Madamagh is of considerable importance for investigating the Paleolithic-Epipaleolithic transition (Schyle and Uerpmann, 1988).

Previously excavated by Kirkbride (1958) and Schyle (reported in Schyle and Uerpmann, 1988), the most recent investigation of the site was conducted by Olszewski and al-Nahar (2011).

Excavation was complicated by damage from sediment slump and erosion. Most of the upper deposits (Early Epipaleolithic) were missing. However, brecciated Early Epipaleolithic deposits adhering to the rock shelter wall and a small area in the north end of the rock shelter were still intact. Notably, a ground stone boulder mortar was uncovered in these Early Epipaleolithic deposits (Olszewski and al-Nahar, 2011). Sediments from this mortar were analyzed for phytoliths. In the south area of the site a larger excavation block was set up. These deposits are Late Upper Paleolithic in origin. The stratigraphy is complicated in this part of the site by a variety of superimposed contexts, including ash dumps and hearth areas (Olszewski and al-Nahar, 2011). This block has also been subject to rodent activity. However, identified disturbances were excavated and screened separately (Olszewski and al-Nahar, 2011). A total of 11 sediment samples were analyzed for this study (Table 1). The site was excavated in arbitrary 3 cm levels within natural levels. Sediment samples were collected from each 3 cm level (Olszewski and al-Nahar, 2011). Sediment samples were also taken from the brecciated deposits (breccia) adhering to the rock shelter wall (Olszewski and al-Nahar, 2011).

4.2 Phytolith Methods

Phytoliths were extracted from the sediments following Rosen's (1999) protocol, which employs a series of techniques to remove carbonates, clays and organics before extracting the phytoliths. First, the sediment was sieved through a 0.25 mm mesh sieve to remove the coarse sediment fraction. A sub-sample of approximately 800mg was weighed and taken for analysis. The sample was treated with 30ml of 10% HCl to remove the carbonates. To disperse the clays, a solution of sodium hexametaphosphate (lab grade Calgon and distilled water) was added to the sample. The clays were removed from the sample by decanting after settling the fine sands and

silts in an eight cm column of water for one hour. This process was repeated until the suspension was clear. Organic matter was removed by dry ashing the samples in a muffle furnace for 2 hours at 500 degrees Celsius. The phytoliths were then extracted from the remaining fraction using heavy density separation. A sodium polytungstate (SPT) solution (with distilled water) calibrated to 2.3 specific gravity was used to separate the phytoliths from the heavier minerals. The phytoliths were then poured off into a clean centrifuge tube, washed in distilled water, dried, weighed and then mounted in Entellan. The phytolith slides were counted at 400 x magnification using a transmitted-light microscope (Nikon Eclipse E200). A minimum of 300 single cells and 50 multi-cells (whenever possible) were counted on each slide. The results are expressed as number per gram of sediment. The absolute counts (number per gm sediment) for each phytolith type were calculated using a modified method outlined by Albert et al. (1999); Albert and Weiner (2001); see Power et al. (2014) for details.

5. Results and Discussion

5.1 Phytolith Assemblage and Ecozone-types

Phytoliths are microscopic silt-sized particles of opaline silica. They are formed when plants take up soluble silica from the ground water. The silica is then deposited in and around the intracellular and extracellular spaces, creating durable inorganic silica ‘casts’ of the plants’ cells. This process is genetically and environmentally determined (Liu et al., 2013; Madella et al., 2009). Grasses, sedges and palms (monocotyledons) readily produce phytoliths, often distinctive to plant family, genus and more rarely, species. Woody trees and other herbaceous dicots also produce phytoliths, although far fewer and with more irregular forms (Albert et al., 2000).

Indeed, grasses produce 20 times more phytoliths than dicot wood and 16 times more than dicot leaves (Albert and Weiner, 2001).

In grasses and other monocots, silica is deposited both passively and actively in the cells of the plant. As a result, phytoliths can form in individual cells, producing single-cell phytoliths, or as a suite of attached adjacent cells, producing multi-cell forms, also known as silica skeletons. By studying the anatomical orientation of these fossilized sections of plant tissue, it is possible to make identifications down to the plant genus or species level. Single cell monocot phytoliths are identified according to the ICPN classification system, where possible (Madella et al., 2005).

Two common monocot phytolith types, ‘psilate long cells’ and ‘rondel’-shaped short cells, dominate all of the samples. Psilate long cells are found in all grasses and sedges, and they have limited diagnostic utility, except as indicators of grass shoots rather than inflorescences. The dominance of ‘rondel’ short-cells however, is important for the reconstruction of the local environmental background. Rondels (generally from pooid grasses) are formed in C₃ grasses, indicating a prevailing temperate climate. However, C₃ grasses tend to have higher moisture requirements than C₄ grasses and the prevalence of C₃ grasses appears to support suggestions that the LGM, while cool, may have been only mildly dryer than the climate in the region today (Weinstein-Evron, 1993). While both cell types are important for discussing general trends in the assemblage, due to the sheer numbers of them, they obscure other patterns of plant-use. Accordingly, neither is used when trying to determine the ecozone-types exploited by Late Pleistocene hunter-gatherers.

To develop a picture of which ecozone-types were being exploited, the phytoliths are grouped in the following categories to identify wetland, steppe/parkland grasses, and woodland

ecozone-types (Table 2, Figure 4). These categories do not necessarily conform to traditional vegetation zones, but rather provide a broad picture of plant-use categories.

Ecozone-type	Phytolith Microfossils
Wetland	Cyperaceae ‘cones’ (Ollendorf, 1992; Ollendorf et al., 1987), ‘fan-shaped bulliforms’ (cf. reeds), reed culm and leaf, <i>Phragmites</i> sp. culm and leaf (Ryan, 2011)
Woodland	Platelets, honeycomb, coarse verrucate, polyhedron (Bozarth, 1992), all irregular dicots
Steppe/Parkland Grasses	Dendritic long-cells, papillae, cereal straw (Rosen, 1993), all husk multi-cells (Rosen, 1992)

Categorizing the phytolith types into ecozone-types is a simple and effective method of tracing larger patterns of plant-use. However, using these categories uncritically may instill a false sense of equivalence. Only those phytolith forms that can be assigned solely to one ecozone-type are employed. A range of other phytolith types that may be found in either wetland or parkland grasses are not utilized under this simplified classification. Consequently, the only phytoliths that can be definitively assigned to the steppe/parkland grasses ecozone-type are the husk or cereal straw phytoliths. The result may be the underrepresentation of this category. The wetland ecozone-type is made up of a range of profuse phytolith-producing monocots that are identifiable to family and/or genus (Cyperaceae and reed grasses, including *Phragmites* sp.). This category may be overrepresented, particularly in comparison to the woodland ecozone-type, which is made up of dicots that produce far fewer phytoliths. However, in the wetland-type category, certain Cyperaceae short-cells have been shown to not preserve well, whereas dicot wood and bark phytoliths tend to be more taphonomically robust (Albert et al., 2006).

In spite of these concerns, the ecozone-type categorizations are useful because they effectively facilitate inter-site phytolith assemblage comparison. Perhaps most critically, this method of categorization provides a simplified characterization of the Ohalo II phytolith assemblage, which can then be compared to the other sites. Extensive macrobotanical investigation at Ohalo II has resulted in a long list of identified plant taxa that were utilized at this site. Accordingly, the phytolith assemblage at Ohalo II provides important contextualization for the representativeness of these categories.

5.2 Phytolith Results

The ecozone-type phytolith results illustrate clearly that wetland resources were consistently employed at all of the sites and were a particular focus in the lake and marsh settings that characterized Ohalo II and Kharaneh IV (Figure 5). High phytolith densities at Ohalo II and Kharaneh IV compared to Tor Sageer, Yutil al-Hasa and Wadi Madamagh, reflect the intense use of phytolith rich reed and Cyperaceae resources (Figure 6), but also indicates the intensity of occupation that could be sustained in these lake and marsh settings. However, the high ratio of woodland-type resources at Tor Sageer and Yutil al-Hasa is interpreted to represent the use of local riparian plants, and along with the consistent use of wetland-type plants, suggests that river-bank wetland resources were a focal point for hunter-gatherers in the Wadi al-Hasa sites . Wetland-type resources, were also regularly employed at Wadi Madamagh, to an extent however, more similar to the Wadi al-Hasa sites. This may indicate that the wetland in proximity to Wadi Madamagh was more similar to the riparian wetland found in the Wadi al-Hasa. Woodland resources were also heavily employed at Wadi Madamagh. It is unclear if these

woody remains reflect riparian woody vegetation, or Mediterranean woodland vegetation, although no diagnostic Oak (*Quercus* sp.) leaf phytoliths were identified in the assemblage.

The results provide direct botanical evidence that hunter-gatherers in the coarse-grained lake and marsh settings (Ohalo II and Kharaneh IV) exploited the wetland-type resources to a greater extent than the hunter-gatherers in the fine-grained micro-mosaic riparian wetland settings (Tor Sageer, Yutil al-Hasa and Wadi Madamagh). This marked dissimilarity may indicate that very different adaptation strategies were being employed in the coarse versus the fine-grained wetland environments. The patterns of settlement at these sites support this interpretation. Ohalo II and Kharaneh IV display evidence for increasing sedentism with the construction of hut structures (Maher et al., 2012a; Nadel et al., 2004; Nadel and Werker, 1999), whereas the Wadi al-Hasa sites and Wadi Madamagh were occupied as part of a more mobile strategy (with short-term and more long-term occupations), based on the repeated use of persistent sites (but see Olszewski and al-Nahar, this volume).

The coarse-grained structure of the marsh and lake wetland environments provided an expansive phytolittoral zone. This resource base could have served as a form of ‘natural storage’ (Lee, 1968). At the sites of Ohalo II and Kharaneh IV, this reliable phytolittoral larder may have supported the dietary and craft/technological needs of the highly intense and increasingly sedentary occupation of these sites. Whereas in the Wadi al-Hasa and at Wadi Madamagh, the inhabitants were able to effectively and sustainably exploit the varied small-scale micro-mosaic environments provided by the riparian wetland, by maintaining their higher mobility to avoid exhausting their resource base. Use of high-ranked adult ungulates and large-bodied tortoises in the Wadi al-Hasa support this interpretation of a more mobile, light occupation strategy (Munro

et al. this volume). The repeated occupation of these sites over several millennia suggests this strategy was a successful and resilient adaptation in these environments.

By categorizing the phytoliths into ecozone-type, it is also possible to discern broad evidence for how foragers used the unique local resource opportunities. At Wadi Madamagh, Tor Sageer and Yutil al-Hasa, the prevalence of woodland-type resources supplemented by wetland-type resources, suggests a reliance on local plant-foods and/or materials and implies characteristic ‘forager’ behavior (Binford, 1980) which assumes people will travel to the resources (but see Olszewski and al-Nahar, submitted for review); whereas, a different pattern appears at Ohalo II and Kharaneh IV. These sites have greater access to large-scale phytolittoral zones, and therefore a dependable natural food-storage repository. This may have facilitated more sedentary adaptations, from which a higher density and proportion of steppe/parkland grasses were employed to enhance and supplement the wetland resources. This may suggest increased use of regional resources and characteristic ‘collector’ behavior (Binford, 1980) – bringing resources to base camps – was a corollary of employing a risk adverse, wetland-oriented adaptation. By tethering their sites to dependable resource-rich lake and marsh wetlands, the inhabitants at Ohalo II and Kharaneh IV may have allowed greater risk-taking strategies for other types of plant and animal exploitation beyond the wetland zones.

Closer inspection of the dendritic phytoliths (from grass-seed husks) versus the long-cell psilates (from grass and sedge stems) reveals that small-seeded grass and wild cereal grains were being exploited to a greater extent at Ohalo II than Kharaneh IV (Figure 7). This phytolith evidence supports our suggestion that Late Pleistocene foraging decisions were shaped not only according to what resources the wetlands offered, but also by what was available in the surrounding steppe/parkland and woodland zone (*sensu* Madsen and Kelly, 2008). The increased

use of wild small-seeded grass and wild cereal grains likely reflects the more varied and mosaic ecology of the lake-parkland ecozones at Ohalo II. Whereas, the comparatively conservative use of wild small-seeded grass and cereal resources at Kharaneh IV, likely reflects the less varied and uniform ecology of the marsh-steppe/parkland ecozones. These patterns may also indicate that the contrast between the productive potential of the wetland, relative to the surrounding landscape (steppe/parkland), was greatest at Kharaneh IV. Consequently, the inhabitants of Kharaneh IV focused their activities towards the reliable wetland resources on offer, whereas the inhabitants at Ohalo II were more inclined to take calculated risks by foraging to a greater extent in the surrounding mosaic landscape.

5.3 Wedded to Wetlands

Hunter-gatherers tend to settle around important sessile resources, such as water and plant communities – and importantly, wetlands contain an abundance of both. While, different types of wetlands will have diverse characteristics and resource opportunities, wetlands generally tend to have high degrees of resource productivity, diversity and reliability relative to *other* settings. This contrast might be made even more evident during periods of increased aridity. Wetlands could have continued to support populations while the surrounding conditions worsened, creating a situation of local abundance in the context of regional scarcity (Nicholas, 2013).

Throughout the arid environmental conditions of the Late Pleistocene, wetland-oriented adaptations were employed as a risk management strategy. Wetland, steppe/parkland and woodland zones formed an integrated resilient system of plant-use, with wetlands providing an especially important focal point. By wedding their settlement and subsistence to the different

wetland zones in the region, hunter-gatherers were able to develop resilient and persistent sites in the Wadi al-Hasa and Wadi Musa region, and more permanent and constructed sites (with earliest evidence of huts) by Lake Kinneret or in the Azraq Basin (Maher et al., 2012a; Nadel and Werker, 1999). Our study demonstrates clearly that Late Pleistocene peoples in the Eastern Levant used the diverse wetlands differently depending on the specific character of the wetland, and the nature of the non-wetland resources surrounding them.

5.4 Future Work

In order to clarify how hunter-gatherers employed plant resources during the Late Pleistocene, further work should focus on evaluating the extent to which wetland resources were utilized in the diet. Lines of inquiry currently ongoing include: 1) more focused microbotanical (phytolith and starch) analyses of site features (huts, hearths, dumps, pits); and 2) expanded starch analyses of ground stone artifacts at Ohalo II and Kharaneh IV. Further work should evaluate how ‘wetland form’ impacts hunter-gatherer adaptations in the Eastern Levant. Lines of inquiry currently ongoing include: 1) more in depth study of modern wetland comparative plant materials with the aim of refining phytolith identifications; 2) investigating the use of saddle short-cell widths as a proxy-indicator for local wetland conditions (aquatic, seasonal or more arid) (Liu et al., 2013); and 3) more off-site phytolith analyses in combination with geoarchaeology to provide a more detailed picture of wetland form and environment.

6. Conclusions

From the Late Upper Paleolithic through the Middle Epipaleolithic our evidence indicates that strategic exploitation of wetland, steppe/parkland and woodland ecozones formed an

integrated resilient system of plant-use, with wetlands providing an especially important focal point. Using the phytolith evidence from Ohalo II as a relative benchmark for the other sites, we found that the phytolith assemblage at Kharaneh IV is the most similar. Ohalo II and Kharaneh IV were both situated next to ‘coarse-grained’ wetlands that may have hosted extensive phytolittoral storage ladders, and the phytolith assemblages at both sites reflect this with high densities of wetland resources. Wadi Madamagh, Tor Sageer and Yutil al-Hasa, were situated in ‘fine-grained’ micro-mosaic riparian wetland settings that would not have had extensive phytolittoral ladders. The phytolith assemblages at these sites reflect this clearly, with far lower densities of wetland resources and a greater emphasis on woodland resources, interpreted to represent the use of local riparian plants.

Foraging decisions were shaped not only according to what resources the wetlands offered, but also in respect to what was, or was not available in the surrounding steppe/parkland and woodland zone (*sensu* Madsen and Kelly, 2008). Our investigation supports this concept by revealing broad evidence for how foragers used the unique local ecological opportunities in the different regions. At Wadi Madamagh and the Wadi al-Hasa sites, subsistence activities were focused on the local riparian resources. At Ohalo II and Kharaneh IV, subsistence activities were tethered to the reliable lake and marsh wetlands. These resource bases provided a dependable natural food-storage repository and may have allowed greater risk-taking strategies for other types of plant and animal exploitation beyond the wetland zones. However, the phytolith evidence shows that small-seeded grass and wild cereal-grain resources were exploited to a greater extent at Ohalo II than Kharaneh IV. This trend in wild grass and cereal exploitation is thought to reflect the differing levels of ecological contrast at these sites, between the productive potential of the wetland, relative to the surrounding landscape. Foraging outside of the wetland

was a riskier prospect for the inhabitants at Kharaneh IV, than it was for the inhabitants at Ohalo II.

Acknowledgments

We would like to thank the principle investigators of the sites in this study, Dani Nadel (Ohalo II), Lisa Maher and Danielle Macdonald (Kharaneh IV), Deb Olszewski and Maysoon al-Nahar (Wadi Madamagh, Tor Sageer and Yutil al-Hasa). This work would not have been possible without their thorough excavation methods and willing collaboration. This work was supported by a Canadian Social Sciences and Humanities Research Council Ph.D. fellowship [award number 752-2011-1728], a National Science Foundation SBE DDRIG [grant number BCS-1418462], and two Council for British Research in the Levant (CBRL) travel grants (2011, 2012) awarded to M.N. Ramsey.

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Figure Captions

Figure 1. Map showing the approximate boundaries of the Azraq Basin and Wadi al-Hasa drainage, and site locations ©Ramsey 2015.

Figure 2. Schematic drawing of wetland margin, a. phytolittoral zone typical to marsh, illustrating rich resource potential, b. phytolittoral zone with steeper marginal grade, comparatively less resource potential ©Ramsey 2013.

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Figure 3. Figure comparing site occupation periods. Dates from published sources, Ohalo II (Nadel et al., 1995), Kharaneh IV (Richter et al., 2013), Tor Sageer and Yutit al-Hasa (Olszewski and al-Nahar, this issue), Wadi Madamagh (Olszewski, forthcoming).

Figure 4. Images of phytoliths recovered, organized by environment-type:

1. Wetland-type phytoliths, 1a. stacked ‘fan-shaped bulliform’ (cf. reeds) (Kharaneh IV), 1b. sedge cones cf. *Scirpus* (Ohalo II), 1c. *Phragmites* culm (Ohalo II);
2. Woodland-type phytoliths, 2a. coarse verrucate (dicot leaf) (Kharaneh IV), 2b. platelet (dicot leaf) (Wadi Madamagh), 2c. scalloped (dicot leaf) (Kharaneh IV);
3. Parkland-type phytoliths, 3a. wild grass husk (Ohalo II), 3b. cereal straw (Ohalo II); 3c. wild grass husk (Kharaneh IV).

Figure 5. Histogram comparing ecozone-type phytoliths. Absolute counts presented below, with percentages displayed above.

Figure 6. Histogram comparing Cyperaceae and reed phytoliths. Absolute counts presented below, with percentages displayed above.

Figure 7. Histogram comparing long-cell psilate (stem) and long-cell dendritic (husk) phytoliths. Absolute counts presented below, with percentages displayed above (scale 50%-100%).

a.

b.

* Ohalo II contains some lithic types that are typical to an Early Kebaran assemblage (for complete discussion see Nadel 2003:228).