NATUFIAN PLANT EXPLOITATION: MANAGING RISK AND STABILITY IN AN ENVIRONMENT OF CHANGE

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Abstract

In attempting to understand the environmental background of agricultural origins in the ancient Near East, a number of scholars have drawn attention to the temporal correlation between the climatic event of the cold/dry Younger Dryas episode (ca. 12,900–11,600 BP), and an apparent shift to intensive cereal collection by Natufian foragers living in the Mediterranean zones of the Southern Levant. However, we have little direct information about Natufian plant use to test and elaborate these scenarios due the scarcity of charred macrobotanical remains at Natufian sites. An alternative solution is the analysis of phytoliths which are proving to be abundant in Natufian contexts. This study reports on phytolith analyses from Early through Final Natufian levels at Eynan (Ain Mallaha), the Late Natufian at Hlazon Tachtit, with comparisons from Early Natufian deposits at el-Wad. These show heavier use of forest resources in the Early Natufian, with a shift to significantly more grass-seed exploitation in the Late Natufian. The use of grasses included as much (or more) wild weed grass seeds as those from wild cereals. The results suggest the Natufians living in the Mediterranean zone of the Southern Levant indeed changed their plant-use strategies with the onset of the Younger Dryas. Here I argue the Natufians developed a very successful and stable adaptation both to the warmer-wetter conditions of the Bølling/Allerød phase (ca.14,500–12,900 BP) in the Early Natufian Period, and then again to the Younger Dryas of the Late and Final Natufian Periods. Seen in this way, the Natufians are an example of a stable and sustainable forager adaptation to major climatic fluctuations. Natufian adaptations were so successful, that there was little incentive for a shift to a cultivation economy in the Southern Levant until well into the Holocene.

Key words: hunter-gatherers, phytoliths, Younger Dryas, agricultural origins, resource ranking, sustainability.

INTRODUCTION

The Natufians occupy a privileged place in our perception of hunter-gatherer societies. Due to their perceived positioning at the threshold of change from complex hunter/gathering to village farming societies, they are presumed to be the pivotal turning point on a road to cultivation. The Natufians also lived at a time in which major climatic changes occurred as the Late Pleistocene gave way to the conditions that would usher in the Early Holocene interglacial. This has led to much innovative research on the role of environmental change as a stimulus to intensification of cereal exploitation in the Early to Late Natufian subsistence economies (Bar-Yosef and Belfer-Cohen, 1992; Bar-Yosef, 1996; Bar-Yosef and Belfer-Cohen, 2002; Goring-Morris and Belfer-Cohen, 1998; Henry, 1989; Hillman, 1996; Moore and Hillman, 1992). It is clear that Late Pleistocene climate change played an important role in shifting vegetation communities, but the question is what changes took place in Natufian plant exploitation, and did these economic shifts really begin a unique trajectory that eventually led to later Neolithic farming societies? Although the importance of climate change in Natufian adaptation strategies was a major contribution to our understanding of these societies, phytolith evidence from Early and Late Natufian sites suggest that in the face of profound climatic deterioration, the Natufians adjusted their plant subsistence economies in ways that are consistent with strategies of other hunter-gatherer groups living in temperate
to low rainfall environments. I will propose that these shifts in resource exploitation strategies did not ultimately lead to the cultivation of wild cereals among Late and Final Natufian groups, but rather provided a stable system of plant exploitation that the Natufians were able to manage for sustainability and consistency rather than change, and that this system was so successful it remained stable for well over 1000 years.

It is reasonable to assume that Natufian plant economies were well attuned to Eastern Mediterranean ecosystems and like other hunter-gatherer groups around the world they had the resilience to shift economic strategies relatively rapidly with natural changes in plant communities within their geographic range. In fact, the Natufians provide an interesting test case in Pleistocene hunter/gatherer adaptations since we can document significant climatic changes that occurred on the cusp between the Early and Late Natufian societies and with increasing information on plant and animal remains from their sites we can begin to record which strategies these hunter-gatherer groups might have employed to better adapt to new climatic conditions. An archaeological record of plant remains is the key ingredient for our understanding of how Natufians made selective choices of plant resources. However, macro-botanical remains are largely missing from the archaeological record. This is the reason why seeking alternative methods for exploring Natufian plant exploitation is imperative. The phytolith record therefore can be a key to supplying much of this missing information.

**LATE PLEISTOCENE/EARLY HOLOCENE CLIMATIC CHANGE**

Today, the Southern Levant consists of three main geobotanical regions including the Mediterranean Zone characterized by a mix of oak (*Quercus calliprinos* and *Q. ithaburensis*), pistachio (*Pistacia palaestina*), almond (*Amygdalus communis*), carob (*Ceratonia siliqua*) and olive trees (*Olea europaea*), the Irano-Turanian Zone that includes steppic grasses and shrubs, and the arid-lands of the Saharo-Arabian Zone which is typified by dry-land vegetation such as chenopods and *Artemisia* (Zohary and Hopf, 2000) (see Fig. 1). These plant communities are well adapted to the typical Mediterranean climatic cycles of cool/moist winters (with average annual temperatures of ca. 12° C), and warm dry summers (average annual temperature equivalent to ca. 26° C). Average annual rainfall ranges from about 100 mm in the Negev Desert towards the south, to ca. 1000 mm in the Galilee to the north of the region (Orni and Efrat, 1980). This paper will deal with material from Natufian sites in what was traditionally considered the “core” region within the Mediterranean Zone of the Southern Levant. In addition to the broad geo-botanical categorization of this zone as an area of Mediterranean forest vegetation, it also includes a mosaic of smaller micro-habitats which include patches of marsh resources as well as localities with populations of
The climatic changes from the Late Pleistocene to the Early Holocene are summarized in more detail elsewhere (Rosen, 2007a). Briefly, beginning with the Late Glacial Maximum (LGM) at ca. 23,000 cal BP, the Southern Levant reached the peak of cool/dry climatic conditions as seen from the oxygen isotope sequences from speleothems in Nahal Soreq Cave (Fig. 2) (Bar-Matthews et al., 1999). This had a major impact on vegetation communities as indicated by the Hula pollen core (Baruch and Bottema, 1991; Baruch and Bottema, 1999) (Fig. 3). If we accept the radiocarbon dates for the Hula core as corrected by Cappers and others (Cappers et al., 1998; Wright and Thorpe, 2003), the lowermost portion of the sequence coincides with the end of the LGM. It shows that vegetation in the Mediterranean Zone was characterized by xeric plants primarily dominated by cheno pods, Artemisia, and grasses, with much reduced forest vegetation. Further up in the pollen sequence the “Bølling–Allerød” phase that coincided with a significant warming trend and glacial retreat in Europe from ca. 14,500–12,900 cal. BP, shows the rapid influx of trees dominated by oak, but also includes olive and pistachio. This abrupt increase in trees including the very warm/moist loving pistachio, has caused some researchers to question the dating of the Hula core, especially in these lower levels. However, as I have argued elsewhere (Rosen, 2007a), this might be explained by the fact that...
the refuge for warm-loving plants was very close to the Hula as opposed to other localities such as Anatolia where the refuges were more distant, and forest recovery might have taken thousands of year longer (Roberts et al., 1999).

This phase of forest expansion also corresponds with the earliest sites identifiable as Natufian (Bar-Yosef, 1996; Valla, 1981, 1998), and continues throughout most of the Early Natufian period. The end of the Bølling–Allerød phase came abruptly at ca. 12,900 cal. BP with the cool/dry climatic conditions that ushered in the well-known Younger Dryas climatic episode. With this Terminal Pleistocene episode of climatic deterio-

Fig. 3. Pollen core from Lake Hula after Baruch and Botema (1999), showing dates corrected after Cappers et al. (1998)
ration, researchers have noted considerable changes in settlement patterns of the Late Natufian populations that inhabited the region at this time. The onset of the Holocene at around 11,700 BP brought the beginnings of warmer and moister conditions, however, according to the Nahal Soreq oxygen isotope determinations, the optimum for warm/wet conditions only occurred at ca. 10,500 BP.

These climatic fluctuations had a profound impact on vegetation communities upon which Natufian populations depended for their livelihood. In order to adapt to them, it is likely that the shift from Early to Late Natufian societies included a change in plant resource rankings that corresponded in part to the expansion and contraction of different vegetation communities. This would be in keeping with the ways that other hunter/gatherer societies living in semi-arid zones responded to such transformations in their environment. Pollen cores from Lake Hula (Baruch and Bottema, 1999) show that the LGM was characterized by steppic vegetation including a mix of *Artemisia*, Chenopods, and grasses. As the climate became warmer and moister in the Bolling/Allerod, *Quercus* (oak), *Olea* (olive), *Prunus amygdalus* (almond), *Ceratonia siliqua* (carob) and *Pistacia* (pistachio) forest vegetation rapidly expanded. This typical Mediterranean forest vegetation would have provided an important source of protein, fats and oils that are found in acorns, almonds, and pistachio nuts. The carob and olive also would have been important resources for foragers. The cool dry conditions that set in rather abruptly with the Younger Dryas led to a rapid decrease in these forest resources, and a corresponding increase in moist steppic vegetation including an expansion of grasses, presenting the potential of an expanded resource base for seed exploitation (Bottema, 1995, 2002).

Given these environmental and vegetation shifts, we would expect the Natufians to change their plant resource exploitation rankings so that forest products would be of primary importance in the Early Natufian, but decline in the Late and Final Natufian in favor of grass seeds. Some aspects of Natufian material culture are consistent with this interpretation, such as the increase in grinding stones from the Early to the Late Natufian (Wright, 1994), but we still need a better plant remains record to provide us with the proverbial “smoking gun” that would give us more precise information on Natufian adaptations. Therefore, in order to facilitate research into the question of how environmental changes impacted Natufian subsistence strategies we need to have more archaeobotanical data from a large number of Natufian sites.

The largest Natufian sites such as Eynan (Ain Mallaha) on the shore of the Hula marsh are significantly bigger than any previous hunter-gatherer sites in the Levant. The sites typically include semi-circular structures with stone foundations and superstructures composed of reeds (Rosen, 2004), burials, possible storage installations, and the remains of grinding stones. Some researchers have suggested that these characteristics are indications of increasing sedentism with growing populations supported by increased exploitation of wild cereals (Olszewski, 1993; Valla, 1998; Wright, 1994). However, phytolith data shown below, suggest that rather than intensification in cereal use leading to domesticated varieties and true agricultural communities in the PPNA, the Natufians were exploiting a wide variety of different grass seeds with no particular selection of cereals.

A comprehensive study of phytoliths from a number of Natufian sites in the Levant can contribute a great deal to our understanding of Natufian plant exploitation strategies. Here, I report on some preliminary results from the initial work on this material, primarily from the site of Eynan in the vicinity of the Hula marsh, northern Israel, with comparisons from the Late Natufian site of Hilazon Tahtit, and results from Early Natufian levels at el-Wad (prepared and counted by M. Portillo, this volume). The proveniences of samples from these two sites are shown in Table 1. Although we are only beginning to increase our data set, some trends are emerging that may have implications for major shifts in Natufian adaptations in the Southern Levant.

**METHODS**

Phytolith processing was conducted in the Phytolith Laboratory at the Institute of Archaeology, University College London. The process of sample preparation begins with a series of clean-
ing techniques to remove calcium carbonates, clays, and organic matter. First, we prepare a ca. 800 mg aliquot of fine-grained sediment (≤ 0.25 mm). We then treat it with 10% HCl to remove calcium carbonate residues. Then the sediment aliquot is washed with filtered water, centrifuged, and decanted two times. A calgon solution (50 g Sodium hexametaphosphate/1 liter distilled water) of 50 ml is added to the samples to disperse the clays. The solution of sediment and calgon is added to a tall beaker and filtered water is added to a height of 8 cm and stirred vigorously. The fine-sands and silts are allowed to settle for one hour and the clays in suspension are poured off. This is repeated until the suspension is clear and the clays are removed. The sample is dried and then burned in a muffle furnace at 500 °C for two hours to remove the organic matter and micro-charcoal deposits. The remaining sediment is then added to a 15 ml centrifuge tube, along with a heavy density solution of Sodium polytungstate calibrated to a density of 2.3 sp.gr. The solution is agitated then centrifuged at 800 rpm for 10 minutes. The suspension with the phytoliths is poured into a clean centrifuge tube and washed with distilled water, and centrifuged three times until the pellet of phytoliths is clean. It is then weighed and mounted on a slide using Entallen. The phytoliths are counted at 400× magnification, and absolute numbers are calculated for each phytolith type by number per gram sediment. Single cell forms are counted separately from multi-celled silica sheets.

RESULTS

The phytolith assemblages from Eynan and Hilazon Tachtit, as well as el-Wad (Portillo et al., this volume) are for the most part dominated by monocotyledons including pooid grasses, common reed (Phragmites sp.), and sedges (Cyperaceae). There are also varying quantities of dicotyledons (woody and herbaceous shrubs and trees). The results can be divided into assemblages from the single-celled phytoliths which pro-

<table>
<thead>
<tr>
<th>Lab number</th>
<th>Sample number</th>
<th>Provenience</th>
<th>Context</th>
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<td>EM 97 6105</td>
<td>Q. 98</td>
<td>Ashy Feature 228</td>
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<td>EM 98 6918</td>
<td>J. 92a</td>
<td>Hearth 224</td>
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<td>EM 98 6976</td>
<td>J. 92d</td>
<td>Hearth 224</td>
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<td>EM 98 7016</td>
<td>J. 92d</td>
<td>Hearth 224</td>
</tr>
<tr>
<td>EM-01-5</td>
<td>EM 99 7250</td>
<td>J. 98a</td>
<td>Burnt material in structure 203</td>
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<tr>
<td>EM-01-6</td>
<td>EM 99 7676</td>
<td>R.97c</td>
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<td>R.97c</td>
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<td>H93d</td>
<td>Structure 227</td>
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<td>G97a and G98b</td>
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<td>Q96b and Q97c</td>
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<td>G98</td>
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<td>K95b</td>
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<td>EM 05 10130</td>
<td>K95a</td>
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<td>EM 05 10167</td>
<td>R97d</td>
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<td>EM 05 9807</td>
<td>Q97b</td>
<td>Locus 215</td>
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<tr>
<td>EM-06-6</td>
<td>EM 05 10133</td>
<td>K98b</td>
<td>In Mortar Locus 241</td>
</tr>
</tbody>
</table>

Table 1

Provenience of phytolith samples from Eynan by lab number
(from Rosen in Valla et al., 2004, 2007)
vide information on plant parts, and grass subfamilies, and those from the multi-celled phytoliths which can indicate genus and sometimes species (Rosen, 1992, 1999).

**Single-cell phytoliths**

Grass and sedge phytoliths derived from single epidermal cells include those in the shape of long-cells, short-cells, bulliforms, trichomes (or micro-hairs), papillae, and others. These cells can be good indicators of the plant parts from which they are derived. The distinctive *Elongate Dendritic* long-cell phytoliths are significant for this study since they form in the husk (glume, palea, and lemma) of the grass which covers the grain, and as such they are a proxy for grass seeds in the single-cell phytolith category. This can be compared with the *Elongate Psilate* (smooth-sided) long-cells which primarily form in the culm and leaves of grasses and sedges, and indicate the shoots rather than seeds of the plant. Phytoliths formed in woody dicots are often more irregular with variable morphologies (Albert and Weiner, 2001) (Fig. 4a). It is therefore more difficult to assign them to family or genus than the monocotyledons, although the leaves of dicots are often more distinctive (Fig. 4b).

Only a few samples from Early Natufian levels at Eynan were available for analysis, but if we examine the ratios of dicots to monocots, these tentatively suggest that woody plants were exploited more heavily in the Early Natufian period and less in the Late Natufian. A comparison of these results with the dicot/monocot ratios from el-Wad supports this trend quite strongly, with consistently high ratios of dicot/monocots at that site (Fig. 5). This shows that although monocots are the prevalent type of plant at all three sites, we can still detect a decrease in the amounts of woody plants being used from the Early Natufian through the Late/Final Natufian periods. This trend is evident at all three of these sites. This tendency would be in keeping with the decline in forests initiated by the onset of cool/dry conditions with the Younger Dryas as seen in the Hula pollen diagram (Baruch and Bottema, 1999), and an hypothesis of decline in available tree and forest resources.

Concentrating on the Gramineae, grass phytolith densities indicate how grasses might have been used at the sites. The small quantities of grass husks (as indicated by low numbers of *dendritics*) in the Early Natufian tentatively suggest that they may not have been heavily exploited for their seeds, but rather for more general uses. In contrast, the Late Natufian samples show...
there are larger quantities of grass husks from the site of Eynan and Hilazon Tachtit, than there were in the few Early Natufian samples at Eynan, and the larger number of Early Natufian samples at el-Wad, suggesting more intensive use of grass seeds in the later periods (Fig. 6). These quantities can be compared to the phytolith results from the PPNA site of Dhra on the east side of the Jordan Rift Valley which show significantly larger quantities of grass-seeds being exploited (Fig 7) (Jenkins and Rosen, n.d.; Kuijt and Finlayson, 2009).

**Multi-cell phytoliths**

There are a number of different multi-cell phytolith types at Eynan and Hilazon Tachtit, but some of the most informative trends come from the densities of wild weed grasses, wild emmer wheat (Fig. 8), and wild barley, as well as the dicots or woody plants. Although we commonly assume that Late/Final Natufians were primarily targeting wild cereals, the phytolith data suggest they were exploiting numerous kinds of wild weed grasses even more than wheat and barley. Figure 9 shows there are high densities of wild grass husks concentrated at specific localities at Eynan that indicate the wild grass seeds were collected, separated, prepared and consumed in the same way that wild cereals were consumed, and even appear in larger quantities than wild cereals suggesting that these smaller-seeded grasses were just as important, or perhaps even more so than the wild cereals in Late Natufian levels at both Eynan and Hilazon Tachtit. It is worth noting that there were very few multi-cell grass phytolith forms from Early Natufian levels at both Eynan and el-Wad.

**DISCUSSION**

Thus far, the preliminary phytolith data seem to support the concept of changing Natufian plant economies with shifting environments from the Bölling–Allerød through the Younger Dryas. This is in keeping with the way many hunter-gatherer societies adjust their resource ranking in response to abrupt climatic change (Haberle and
However, we need to ask if there was something unique in the Natufian adaptation to this change which might have led them on an irreversible path to cultivation, or alternatively, as argued here, was the Natufian adaptation of collecting wild grasses, a stable sustainable system that reached a kind of steady state of equilibrium with the environmental setting that required no transformation to actual planting and cultivation of wild cereals?

It’s informative to compare Natufian plant exploitation strategies with other hunter/gatherers who were faced with similar situations of abrupt climate change. Human Behavioral Ecologists have suggested a number of ways in which hunter/gatherers typically respond to adverse environmental change in order to manage the risk versus desirability of subsistence resources. They have identified several recurrent principles that are useful to consider in the case of the Natufians.

The concepts of “resource choice” and “risk minimization” used in HBE models are helpful when considering possible responses to climate change on the part of the Natufians. Foragers will commonly opt for smoothing over episodes of booms and busts by selecting resources with lower mean payoffs, but greater stability. They will tend to concentrate on foods that are readily attainable and dependable, thus minimizing risks, even if these foods are normally considered famine foods (Kennett and Winterhalder, 2006; Low, 1990; Minnis, 1985).

Ethnographic hunter-gatherer studies around the world contrast the exploitation of nuts and acorns with that of grass seeds. Many foragers will rank nuts higher than seeds due to their high nutritional value, their ease of collection and processing, and the lack of a need for complex tool kits for their exploitation (Keeley, 1992; Lee, 1979; Mason, 1995). In contrast, grass seeds are given a lower ranking since they require more en-

![Fig. 6. Increasing frequencies of grass-husks from the Early to Late/Final Natufian Periods as indicated by numbers of elongate dendrites (long-cells from husks). These are a proxy for grass seeds](image-url)
ergy to collect and process, and often involve specialized toolkits such as grinding stones, beaters and baskets. Researchers have looked for a change in environmental conditions as an explanation for a hunter-gatherer group switching their emphasis from a high-ranked plant resource such as nuts or acorns, to a low ranked one such as grass seeds.

A number of such case studies are analogous to the situation faced by Natufians during times of abrupt environmental change (Table 2). During such episodes, many hunter-gatherers will turn to more predictable resources, and a strategy of diversification, even if these resources require more effort to collect, and specialized toolkits for collecting and processing. Such was the case when ancient Californians were faced with environmental changes from warm moist to cool dry conditions ca. 500–1300 CE (Kennett and Kennett, 2000). This was accompanied by a decrease in terrestrial resource use, but a flourishing of ma-

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**Fig. 7.** Comparison of low Natufian husk/stem ratios with higher ratios from PPNA Dhra in the Jordan Valley

**Fig. 8.** Multi-cell phytoliths from the husks of wheat (*Triticum* sp.), from Late Natufian Eynan. Scale bar = 10 µm
rine resource exploitation. In the case of these Late Holocene Californians, strategies shifted away from the parkland environments, towards the more predictable marine environments, although these required technological specializations and a greater output of labor. Likewise, studies from Cape York in Northern Australia show similar trends (Haberle and David, 2004). Here, climatic proxies indicate decreasing rainfall levels and increasingly open vegetation after 3500 cal. BP. The apparent response to these environmental changes by local hunter-gatherers was a decrease in group size, an increase in territoriality as manifested in the regionalization of rock-art styles after this time period, more intensive use of plants within smaller ranges, an increase in the exploitation of grassland areas, accompanied by more seed-grinding stones, and consumption of new species including toxic plants.

A similar situation is reported from the North American Great Plains when drying climatic conditions set in during the Middle Holocene (Meltzer, 1999). With a reduction in water sources, bison populations decreased and water sources became more limited. Responses on the part of hunter-gatherer groups varied, but some similarities included greater selection of lower-ranked/higher-cost resources such as grass-seeds, and new technologies for exploiting and processing these grass-seeds, including grinding stones, earth ovens and storage pits.

Thus research into general hunter-gatherer foraging strategies suggests that grass seeds are often a lower-ranked resource than nuts, and when given the opportunity, nuts or other protein rich resources will take precedence over the exploitation of seeds (Barlow and Heck, 2002). The use of grass seeds and other plants with high processing costs will tend to increase when environmental conditions or population decreases reduce the availability of nuts (Keeley, 1992).

This common hunter-gatherer strategy for managing risk seems very relevant to Natufian adaptations throughout the Bolling–Allerød war-

Fig. 9. Frequencies (in number per gram sediment) of multi-cell phytoliths from wheat (*Triticum* sp.), barley (*Hordeum* sp.), and wild weed grasses at Eynan (Early-Late/Final Natufian) and Hilazon Tachtit (Late Natufian)
ming in the Early Natufian and the Younger Dryas climatic deterioration in the Late Natufian. So far, the phytolith samples from Early Natufian el-Wad and Eynan, and the Late Natufian levels at Eynan and Hilazon Tachtit are in keeping with the patterns predicted by these Human Behavioral Ecological models. The fact that there was an increasing emphasis on grass seeds from the Early Natufian to the Late Natufian has been suggested by numerous researchers (Bar-Yosef and Belfer-Cohen, 1991; Bar-Yosef, 2002; Henry, 1989; Hillman, 1996; Wright, 1994) based on increasing numbers of grinding stones from Early through Late Natufian. The preliminary phytolith data appears to support these other data sets. However, it does not appear that the Natufians were specifically targeting wild cereals nor were they headed for an agricultural lifestyle. The phytolith evidence from Eynan and Hilazon Tachtit shows that cereals were only a portion of the wild grasses exploited by the Natufians. In keeping with other hunter/gatherers under stress, it is likely that the significant Natufian adaptation was to grass seeds in general, and not exclusively to cereals (Rosen, 2007b). This would preclude models of “self-domestication” of cereals and conscious human selection for the stiff rachis in wild wheat, both of which would support direc-

### Table 2

Case studies of hunter-gatherer adaptations to environmental change (after Rosen 2007a)

<table>
<thead>
<tr>
<th>Case study</th>
<th>Environmental changes</th>
<th>Changes in resource choice</th>
<th>Settlement changes</th>
<th>Intergroup interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Californians&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Warm moist to cool dry; increase in marine resources; decrease in terrestrial resources; less water available</td>
<td>Increased use of more predictable resources: use of more marine and less terrestrial; diversification acquired through trade rather than mobility</td>
<td>Increased sedentism to claim good fishing areas and fresh water sources</td>
<td>Increase in competition and hostility, but also increasing cooperation and trade</td>
</tr>
<tr>
<td>N. Australia&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Decreasing rainfall; greater steppic vegetation</td>
<td>Broader subsistence base - more diverse resources used in smaller area; labor-intensive seed grinding and use of toxic plants</td>
<td>Breaking up into smaller groups; greater territoriality</td>
<td>Increase in territoriality</td>
</tr>
<tr>
<td>North American&lt;sup&gt;3&lt;/sup&gt; Plains</td>
<td>Drying conditions; fewer water sources; reduction in primary resource: bison; increase in grasslands</td>
<td>Increase in lower-ranked/higher-cost resources; new food-processing technologies such as grinding stones for grasses</td>
<td>Relocation to permanent water sources; more permanent settlement; fewer sites; more evidence for storage</td>
<td></td>
</tr>
<tr>
<td>Early Natufians (ca.14,500-13,000 cal. BP)</td>
<td>Warming and moist; increasing forests, including Pistacia and Quercus</td>
<td>Use of forest resources such as acorn and pistachio&lt;sup&gt;4&lt;/sup&gt; (primary?); and grass seeds (secondary?); lower subsistence risks; possible storage in baskets&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Increase in population in the Mediterranean zone; increasing sedentism and relatively large hamlets; architectural innovations; more sickles; more groundstone; more diverse toolkit; art</td>
<td>Restricted territorial ranges; well-developed exchange networks&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Late/Final NatufiansLate: (ca.13,000-11,600 cal. BP)</td>
<td>Drying climate with Younger Dryas; decrease in forest, increase in grassland&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Possible decrease in forest resources such as pistachio and acorn; increase in grinding stones and sickles for harvesting in grasses; burning of land to maintain grasslands? possible storage of seeds? increase in water fowl, depletion of gazelle</td>
<td>Decrease in sedentism and dispersal of smaller population groups; toolkits still include sickles and an increase in groundstone mortars&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Increase in territoriality; trade from the south as well as the Mediterranean&lt;sup&gt;9&lt;/sup&gt;</td>
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<sup>1</sup> (Kennett and Kennett, 2000); <sup>2</sup> (Haberle and David, 2004); <sup>3</sup> (Meltzer, 1999); <sup>4</sup> (Bar-Yosef and Belfer-Cohen, 1992); <sup>5</sup> (Goring-Morris and Belfer-Cohen, 1998); <sup>6</sup> (Baruch and Bottema, 1991); <sup>7</sup> (Bottema, 2002); <sup>8</sup> (Wright, 1994); <sup>9</sup> (Bar-Yosef and Belfer-Cohen, 1991)
tional changes leading Natufian foragers from collection of wheat in the wild, to cultivation of wild wheat and onward towards eventual farming of domestic varieties of wheat in the Pre-Pottery Neolithic (PPN). These models may be applicable for populations in the PPN, but given the evidence for Natufian collection of a wide variety of grass genera, without privileging wild cereals, these scenarios seem less applicable to the Natufians.

CONCLUDING REMARKS

Although the Natufians seem to have followed a strategy of changing resource ranking with changing environmental regimes, this alone was not enough to set them on the path to agriculture. In fact, small and large grass-seed exploitation seems to have been such a successful adaptation to the Younger Dryas cool dry environment that it continued to persist for about 1500 years. Thus I suggest that the Younger Dryas climate change was not a forcing mechanism for the development of agriculture, rather a shift that required a move to a new foraging equilibrium on the part of the Natufians.

The Late UP or Early Epipaleolithic inhabitants of Ohalo II are a good analogy for Late Natufians in the Mediterranean Core Zone. Like the Natufians, they had to deal with a very harsh cool/dry climate. It is well-understood that the Ohalo II populations also exploited grass seeds intensively from a wide variety of different grass genera (Kislev et al., 1992; Piperno et al., 2004). According to the HBE model, this would have been a very successful strategy for a period of time which was characterized by reduced forest resources, and dominated by steppic vegetation.

If the Natufian response to climate change was not unique, but rather along the lines of normative hunter/gatherer reactions to climate change, then we would have to look for agricultural origins in the Holocene, most likely as a result of both social ‘push’ and climatic ‘pull’ factors resulting from growing populations and climatic ameliorations reducing the risk involved in farming.

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Notes
1. It is important to reiterate that this scenario of Late Pleistocene vegetation changes is based on the original radiocarbon dates from the Hula core which were corrected by Cappers et al. (1998). Meadows’ readjustment places the lowermost portion of the core at the Younger Dryas, thus excluding the time period of the Bølling/Allerød, and a new readjustment of dates by van Zeist and Baruch (2009) would push it even younger so that the whole core only covers the Holocene. My rationale for sticking with the Cappers date corrections is outlined in Rosen (2007a), since these seem to also be consistent with more recent cores in the Ghab valley of northern Syria. Until there are new dates or some general consensus of which correction is most reasonable, I will use the Cappers et al. correction.