



Changing Settlement Organization in the Late Pleistocene of the Wadi al-Hasa, West-Central Jordan

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Abstract

Since the 1980s, surveys in Jordan's Wadi al-Hasa document dozens of Late Pleistocene hunter–gatherer sites, some of them tested or partly excavated. To track landscape-scale forager mobility and settlement patterns over time, we examine 26 levels from 13 sites dated to the Middle, Upper, and Epipaleolithic using aspects of Barton's whole assemblage behavioral indicators research protocol, a collection of methods designed to extract patterns from archeological palimpsests. Because forager ethnographies document adaptive strategies that do not map onto the discrete site types employed by archeologists, we evaluate the utility of the latter so far as behavioral inferences are concerned. We show that discrete bimodal contrasts like “curated” and “expedient” and their archeological correlates fail to capture the much more complex reality. Only by using these methods in conjunction with these analytical contrasts can a realistic picture of forager mobility and land use approximating that known from ethnography be attained.

Keywords Wadi al-Hasa · Paleolithic · Whole assemblage behavioral indicators · Mobility

Introduction

The settlement-subsistence systems of prehistoric foraging societies have long been a topic of interest to archeologists. Ethnographic and historical accounts indicate that hunter–gatherers produce a variety of site types based on seasonality, access to resources, degree of residential mobility, and site function (Bettinger, 1991; Binford, 1980; Kelly, 1995; Yellen, 1977; see Kuhn et al. (2016) for a current appraisal). As a result, the composition or archeological “signature” of the remains is expected to reflect, to some degree, these situationally based factors. In many cases, all we have to work with is a large quantity of chipped stone and, sometimes, a meager amount of fauna as our database for interpreting patterns of settlement organization. The usefulness of the latter is largely dependent on a combination

of factors including the age of the site, the degree of preservation which is driven by exposure, and whether it is an open site or a cave/rock shelter location. This issue of preservation is particularly true in the xeric environments of the Levant, where late Pleistocene sites were affected by subsequent alluvial and erosional activities during the early to mid-Holocene (Schuldenrein & Clark, 2001, 2003; see Clark et al., 2017 for an overview).

In this paper, we try to untangle evidence for forager mobility patterns in Jordan's Wadi al-Hasa using whole assemblage behavioral indicators (WABI), a collection of methods for assessing site functions in regional contexts using the characteristics of whole lithic assemblages in conjunction with site distributions and features of the landscape. One of several approaches intended to free us from the techno-typological constraints of cultural history, WABI was first introduced by C. Michael Barton in 1998 (Barton, 1998) and has since been adopted and expanded by later researchers as a means of assessing archeological palimpsests (e.g., Clark & Barton, 2017; Riel-Salvatore & Barton, 2004; Villaverde et al., 1998). First, we address the culture historical approach to stone tools noting the limitations of such approaches in light of continuous variation in stone artifacts. Second, we present the WABI approach to lithic assemblages with an emphasis on lithic volumetric density

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(LVD) as a means of addressing assemblages on the curated to expedient continuum. Finally, we apply a WABI approach to Late Pleistocene sites from the Wadi al-Hasa region to assess their fit to the expectations of foraging settlement strategies. At a meta-level, there is a moderately good fit with the expectations of forager behavior along the curated-expedient continuum—this is more clearly demonstrated at the level of the different time/stratigraphic units. Ultimately, bimodal contrasts like “expedient” and “curated” fail to capture a more complex archeological reality. WABI methods, applied in conjunction with these analytical models, are an important first step in understanding forager mobility and land use in prehistoric settlement systems.

Cultural History and Conventional Systematics

Historically, assessments of variability in Stone Age lithic collections usually have deployed conventional techno-typological systematics to allocate assemblages to the various prehistorian-defined analytical units that comprise the Paleolithic (e.g., Bordes, 1953, 1961; de Sonneville-Bordes & Perrot, 1953). Originating in France in the last quarter of the nineteenth century and exported to the Middle East prior to World War II, conventional systematics have a respectable pedigree and have contributed much to our understanding of Paleolithic forager adaptations in space and time. However, novel methodologies have arisen over the past 25 years because of growing dissatisfaction with the explanatory potential of cultural history, now seen to be limited insofar as behavioral inferences are concerned. Below, we offer a brief history of techno-typological approaches and the critiques leveled at them by anglophone researchers in the US, UK, Canada, and Australia (see also Clark et al., 2019: 176–179).

Throughout much of the twentieth century, archeologists interpreted patterns in stone tool assemblages as the material consequences of the mental templates ancient peoples used for their manufacture (e.g., Bordes, 1953; Hours, 1974). A key assumption underlying this approach was that artifact typologies captured, to some degree, ideal tool forms held in the minds of people long dead, and variations in these forms mapped onto different groups of identity-conscious social units analogous to archeologists’ ethnographic understanding of hunter–gatherers. Stone tools and their distributions through time and space were taken to mark the boundaries of prehistoric foraging societies. Scathing criticism of this approach by social anthropologists (e.g., Owen, 1965: 675–690) was almost completely ignored.

Where did this paradigm come from? First proposed by French prehistorians in the nineteenth century (e.g., de Mortillet, 1883; see Sackett, 1991 for an overview), the

inferential logic of cultural history was then applied to lithic technology with the appearance of methods lumped under the rubric of behavioral chain approaches (*chaînes opératoires*) that sought—commendably—to extend analysis beyond the limitations of typology (e.g., Boëda et al., 1990). Widely regarded as an advance in conventional systematics, the *chaîne opératoire* gained traction during the 1990s and spread widely throughout the Old World, especially in the francophone research traditions (Audouze & Karlin, 2017). Despite its acknowledged utility, however, pattern recognition remained locked into the same explanatory framework as typology (see Clark & Riel-Salvatore 2006, 2009 for an extended critique).

Building upon the notion of continuous morphological variation first proposed by Frison (1968), Dibble (1987, 1995) demonstrated unequivocally that Middle Paleolithic sidescraper morphology, attributed in the Bordesian typology to intentional design (e.g., Bordes, 1953), most likely reflected original blank size and shape, and the intensity of retouch prior to loss or discard. This concept was applied to other analytical units as a means of understanding variation in artifact variation and frequency (Barton, 1991; Sackett, 1988). Importantly, this perspective calls into question the notion of design specificity in the manufacture of *all* chipped stone artifacts, resulting in a sequence of edge modifications determined mostly by initial blank morphology and retouch intensity (Clark, 2009). Stone tools recovered from archeological contexts came to be seen as items at the end of their “use-lives” when additional modification is no longer possible or practical (see also Bleed, 2001; Hiscock, 2007; Holdaway & Douglass, 2012).

Approaches to Modeling Hunter–Gatherer Settlement

The approach taken here departs significantly from the cultural–historical framework just outlined insofar as the incidence of retouched stone artifacts is taken to measure *only* the relative degree of mobility and duration of site occupation. It has nothing to do with social identity writ small in artifact form, the mental templates by which formal similarity is conveyed, nor lithic traditions passed down from one generation to the next. The rationale for the approach is explicated elsewhere (e.g., Barton, 1991, 1998; Clark & Riel-Salvatore, 2006) but is based on solid evidence that—with very rare exceptions—all Pleistocene sites are palimpsests, depositional composites that do not reflect the contemporaneous activities of any narrowly circumscribed group of people (see, e.g., Barton, 1991; Barton & Clark, 2021; Barton & Neeley, 1996; Clark & Barton, 2017). Put another way, no face-to-face interaction drives a pattern in the coarse-grained time/space grid of the archeology of

“deep time”. These observations call into question the inferential logic of cultural history, its credibility as a conceptual framework, and the systematics upon which it is based.

Despite terminological differences, there is a structural similarity to efforts to model the theoretical composition of ancient lithic assemblages. They tend to use dichotomies to describe settlement modes applied to time-factored site distributions at the regional scale. Examples include Binford’s residential/logistic mobility (Binford, 1980), Marks and Freidel’s radiating/circulating dichotomy (Marks & Freidel, 1977), and Kuhn’s personal and place provisioning (1992, 1994), each with overlapping and consilient, but somewhat distinct, expectations about pattern. It is important to emphasize that these dichotomies are deployed for heuristic purposes only. It has always been recognized that settlement organization is continuous rather than discrete and that hunter–gatherers frequently adopted shifting strategies between these extremes as part of their seasonal and annual activities (Riel-Salvatore & Barton, 2004). Insofar as patterns can be discerned, what we are probably seeing are time-averaged site types that indicate places in the landscape used over the long term for similar purposes (e.g., Olszewski & al-Nahar, 2016). In sites with exceptionally complete data, the approach can be used to identify “structural poses” (Gearing, 1958) on a level-by-level basis within a single site (e.g., Clark & Barton, 2017).

The empirical referents of these structural poses are by no means straightforward and have been much discussed.

Some researchers have used site size and artifact density to distinguish between different site types (e.g., Bar-Yosef, 1998; Henry, 1994, 1995; Henry et al., 2004). Others argue that expedient technologies correspond to longer-term residential bases and that curated technologies indicate short-term limited activity stations (e.g., Parry & Kelly, 1987). This is the approach taken here. The general expectation is that the length of occupation is linked to the kinds and frequencies of activities, hence artifacts and features, found in these idealized site types. Lower residential mobility (e.g., radiating or logistical organization) is more likely to be associated with expedient technologies, whereas higher residential mobility (circulating or residential mobility) is more likely to be indicated by curated technologies. Aspects of these strategies have been explored in terms of artifact densities by unit area or volume, spatial distribution, the relative frequency of cores, retouched pieces, debitage, the extent of cortex on unretouched flakes and blades, and the presence or absence of features (middens, hearths, pits, etc.). Based for the most part on WABI, a recent example of the criteria used to distinguish between expedient and curated technologies “on the ground” is given in Table 1. These criteria serve as a starting point for interpretation rather than an actual expectation of patterns in the archaeological record. The ideal pattern is a strong negative correlation between low artifact density and high tool frequency (curation), on the one hand, and high artifact density and low tool frequency (expediency), on the other (Fig. 1).

Table 1 The material correlates of mobility (Clark et al., 2019)

A high incidence of retouch and low lithic volumetric density is consistent with:

Less residential stability (= transient camps)
 Shorter duration of site occupation
 Smaller sites, local groups (= seasonal fission)
 Resources procured by moving the entire group (moves people to resources)
 A large number of retouched pieces relative to lithic totals
 No cores and little debitage
 Expected to occur during dry, cold intervals with scarce, widely distributed resource patches
 Consistent with increased mobility and the provisioning of individuals

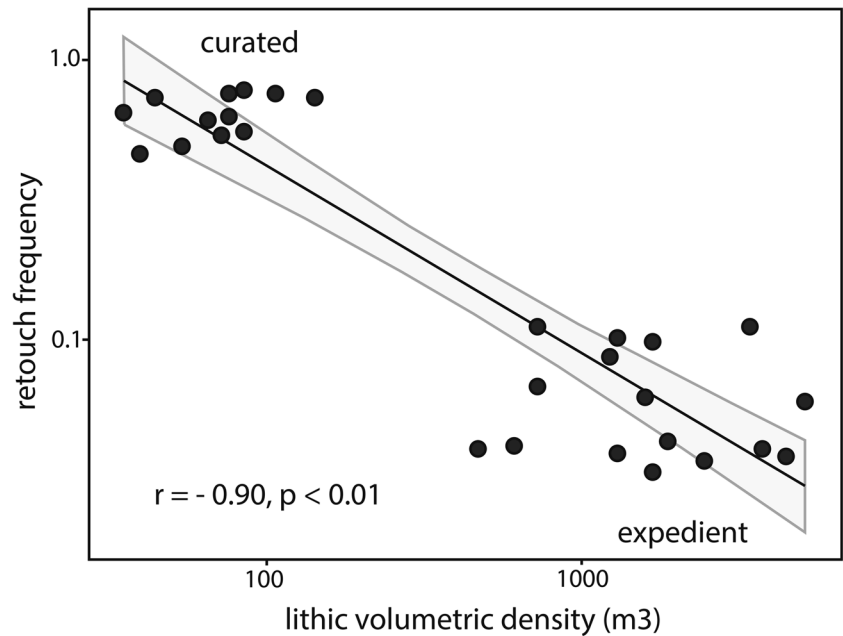
Consistent with **curated assemblages**

A low incidence of retouch and high lithic volumetric density is consistent with:

Greater residential stability (= base camps)
 Longer duration of site occupation
 Larger sites, local groups (= seasonal fusion)
 Resources procured by task groups deployed from residential bases (moves resources to people)
 A small number of retouched pieces relative to lithic totals
 Significant numbers of cores, unretouched flakes and blades, debitage
 Consistent with reduced mobility and the provisioning of places
 Expected to occur during warm, wet intervals with abundant resources in close proximity to residential bases

Consistent with **expedient assemblages**

Fig. 1 Log of lithic volumetric density (LVD) plotted against the log of the frequency of retouched pieces—a hypothetical example showing nearly perfect segregation between curated assemblages (upper left) and expedient assemblages (lower right) (Clark & Barton, 2017)



Whole Assemblage Behavioral Indicators (WABI)—Applications

WABI developed as a reaction to the limitations of the techno-typological systematics upon which cultural history is based (Barton & Clark, 2021; Clark, 1993, 2009; Clark & Riel-Salvatore, 2009). Although the exegesis of the WABI model dates to 2004 (Riel-Salvatore & Barton, 2004), the WABI model in its nascent form was created by C. Michael Barton in a study of Paleolithic settlement and mobility strategies in Gibraltar where he identified a strong negative relationship between artifact density by volume of excavated sediment and the relative frequency of retouched artifacts (Barton, 1998). Adopting Binford's (1987) terminology and Kuhn's (1994) distinction between place and personal provisioning, he suggested that this pattern reflected a continuum from expedient (residential bases) to curated (overnight camps) that had behavioral implications for group size, site function, and relative mobility.

Expedient assemblages should have higher lithic densities per unit volume and lower proportional frequencies of retouched pieces because proximity or access to known sources of tool stone led to decreased necessity for wringing maximum utility from it and consequently less need to resharpen to extend the use-life of lithics. Sites or levels with expedient technologies would be occupied by larger groups of people for longer periods of time, would have significant numbers of cores and other heavy artifacts, less core preparation, all stages of reduction, and large amounts of debitage—all indicators of an absence of resource scarcity. Behaviorally, expedient assemblages could result from the provisioning of places through either embedded or direct

procurement of raw materials. Curated assemblages should have significantly lower lithic densities, higher proportional frequencies of retouched pieces, and few or no cores or other heavy objects—in short, lightweight, flexible, portable tool kits that can be readily adapted to unforeseen circumstances where foragers must depend only on the tools they carry with them. This strategy involves the provisioning of individuals in which the needs of transport effectively create resource scarcity, even when passing through raw material sources. A small hunting party deployed for a short time from a residential base in unfamiliar territory is an example.

The attraction of the WABI approach is threefold. First, these data are relatively easily obtained for a wide range of archeological sites and are often available in site reports and monographs. Second, WABI can be applied across different techno-typological groups as a means of comparison even though the typological underpinnings (e.g., Middle Paleolithic, Upper Paleolithic, Epipaleolithic) are very different. Third, it utilizes the entire range of lithic data, rather than just the retouched pieces. However, the interpretation of results tends to be context-specific as absolute thresholds do not exist and assemblages are evaluated in relation to one another. To better understand the results, we must examine sites along a continuum of behavior and view sites as more or less curated or expedient relative to others.

Limitations of WABI Applications

It should be made explicit that WABI applications are a form of meta-analysis based on broad statistical analyses across multiple studies in order to detect patterns cross-cutting

these datasets (Glass, 1976; Walker et al., 2008). Data requirements for an idealized WABI analysis are presented in Table 2. While the methods are relatively straightforward, the data for a complete WABI analysis can be difficult to find in pre-1990 site reports, and even more recent publications may lack the necessary data for such an analysis. As a result, most WABI applications use a more limited or simplified scope of data.

Successful archeological applications of WABI can be found in both New and Old World research. In a highly influential study, Parry and Kelly (1987) used wide-ranging datasets to identify significant relationships between levels of mobility and incidence of retouching in the New World. In earlier high mobility settings, retouch frequencies were higher whereas in later, more sedentary contexts, retouch frequencies were lower. Similarly, WABI analyses of nearly 200 assemblages from various Old World contexts showed significant negative relationships between lithic volumetric density (LVD) and retouch frequency (Barton et al., 2013; Clark & Barton, 2017; Clark et al., 2019; Kuhn & Clark, 2015; Riel-Salvatore & Barton, 2004, 2007; Riel-Salvatore et al., 2008; Sandgathe, 2006; Villaverde et al., 1998).

Although theoretically possible, we emphasize that very few—if any—assemblages are either wholly curated or wholly expedient (see Clark & Barton 2017: 138 for a

hypothetical example). That said, it should nevertheless be possible to arrange a series of assemblages along a curated/expedient continuum and draw some conclusions about the relationship of one assemblage to another within a single site sequence (e.g., Clark & Barton, 2017), across many site sequences (e.g., Clark et al., 2019), and within and across regions (Popescu, 2015; Riel-Salvatore & Barton, 2004).

Although computing LVD is a straightforward process, it is important to understand why the position of an assemblage on a graph like Fig. 1 can change. Changes in artifact density will move values to the left or right on the x -axis, but it should not be assumed that human behavior is the only significant cause for this. Site formation processes are also important. In particular, the rate and type of sedimentation (aggrading, deflating, or both) will affect this value regardless of any associated behavioral component. Holding behavior constant, sites with rapid deposition would tend to yield lower artifact densities overall than those with a slower rate of deposition. Similarly, surface deflation would tend to increase artifact densities, giving the impression of more stable or longer-term occupations. In contrast, the y -axis values are not impacted by site formation processes because they are based only on the proportional relationship between the retouched component and the total lithic assemblage. Since these are not a byproduct of the density of artifacts per unit excavated, these values are always constant. The only way they can move up or down is as a consequence of some kind of human activity at the time of occupation (e.g., more or less retouch, more or less debitage). Thus, despite the observation that sedimentation rates can shift assemblages to the upper right or lower left of a graph (Riel-Salvatore & Barton, 2004: 261), these movements are not possible since retouch frequency is not affected by sedimentation rates and is independent of artifact density.

It is also worth noting the difficulty of calculating artifact densities when sites are excavated by arbitrary levels (spits), as is often the case in the xeric environments of the Levant. True caves with long, well-defined stratigraphic sequences are rare in Jordan, confined to the northwest corner of the country, and are unknown in the Wadi al-Hasa. Arbitrary levels are the only option in sediments with no discernible stratigraphy. Archeologists are put in the unenviable position of having to balance how fine spits can be in order to maximize vertical control against the host of time constraints involved in making progress with the excavation. Depending on how good (or lucky!) project directors are at making these decisions, these arbitrary slices may incorporate more or less sediment relative to the lithic component of any particular analytical unit (e.g., square, level, sequence), resulting in distortions of the LVD statistics. Extracting these values from field reports, even when artifact frequency and sediment volume are reported, introduces yet another aspect of uncertainty in an analysis of this kind.

Table 2 Data requirements for a complete WABI analysis (Clark et al., 2019)

Archeological variables

Sites

Assemblages within sites

Area excavated in square meters

Mean level thickness in centimeters

Volume excavated in cubic meters

Total number of lithics (flakes, blades, debitage, shatter)

Total number of cores and core fragments

Lithic volumetric density (LVD)—total lithics/volume excavated

Total number of retouched pieces

Percent retouched of the total number of lithics

Backed bladelet index (ib/b)—total backed bladelets/total retouched pieces

Attribution (Ahmarian, Kebaran, Natufian, etc.)

Landscape and environmental variables

Elevation in meters above sea level

Distance to sea (air) in kilometers

Distance to the sea (walking) in kilometers

UTM coordinates

Distance to other contemporaneous sites

Chronological variables

Radiocarbon dates

Marine isotope stages (MIS)

Phytogeographic associations (Irano-Turanian, Saharo-Sindian, etc.)

Application to the Wadi al-Hasa

The west-central Jordan datasets represent a time span between c. 180 and 12 ka BP. They comprise 26 assemblages from 13 sites primarily from the southeastern 18–20 km of the Wadi al-Hasa and its southern tributaries (Abu ed-Diba, er-Ruweih, Ahmar, el-Ali), along with the Wadi al-Qusayr, some 20 km to the south (Fig. 2). The rationale for the selection of multiple assemblages from a small geographic area was to minimize variation that could be attributed to differences in raw material, food resources, elevation, and biogeographic zones that would distort pattern in a more geographically extensive study. For each analytical unit (sites, levels within sites), sediment volume excavated in cubic meters (m^3), debitage, and the number of retouched pieces were recorded. The database consisted only of excavated samples; no sites that were strictly surface collections were

included in the study (Table 3). In the sections below, we identify the trends as they pertain to the expectations of the model, followed by a discussion of what they might mean for our understanding of forager settlement strategies.

First, we examine all sites and assemblages as a single cluster. This minimizes differences due to paleoenvironmental factors that likely impacted resource availability and abundance. Second, the assemblages are divided into rock shelters and open-air contexts. The intent here was to ascertain if different depositional contexts influence the trends. Finally, the sites/assemblages were examined by temporal units corresponding to the major divisions of the Paleolithic and Epipaleolithic used in the Levant. The latter suggests some differences that are obscured in the two previous analyses. It should be kept in mind that, because of relatively few radiometric dates (Table 3), the temporal units are “coarse-grained” compared with better-dated stratigraphic sequences

Fig. 2 Map with location of sites in the eastern end of the Wadi al-Hasa

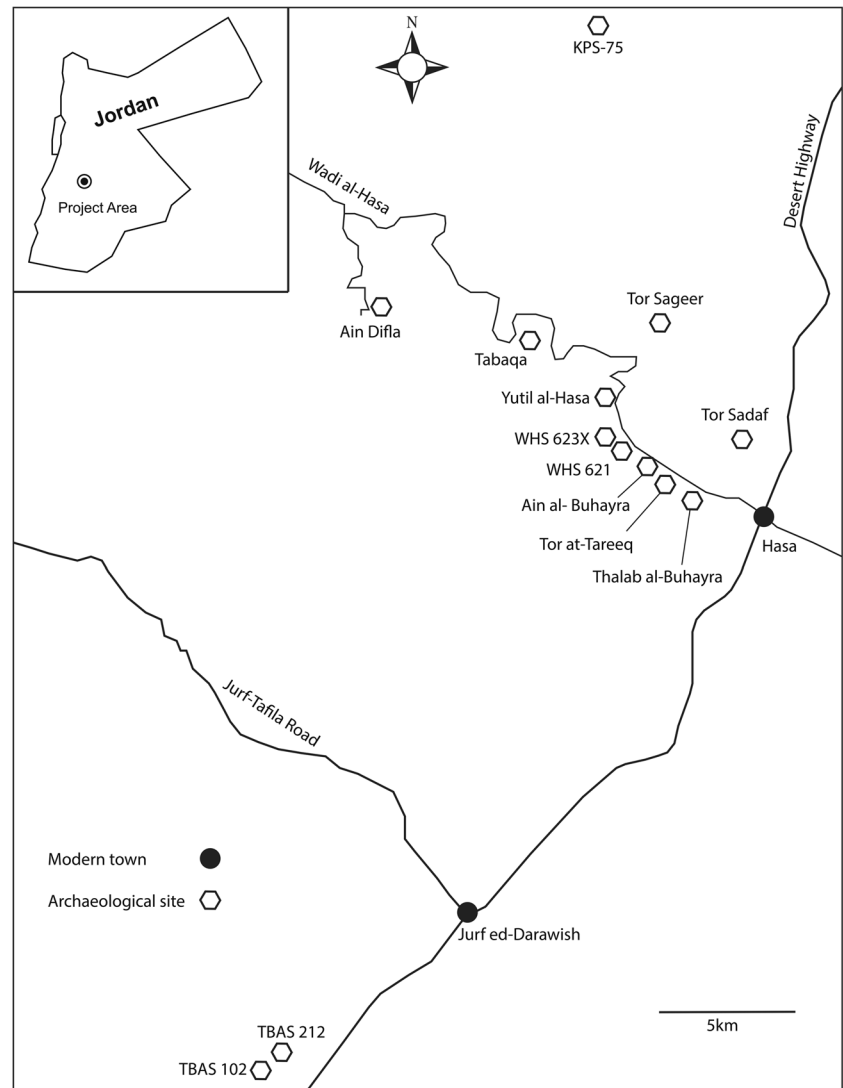


Table 3 Radiocarbon dates and culture/stratigraphic units from excavated sites in the Wadi al-Hasa region

Site	Survey ¹	Analytical unit	Radiometric date (BP)	Calibrated age (95.4% probability ² ; cal BP)
Ain Difla	WHS	Middle Paleolithic Tabun D	Test A, Lev. 5 (105 ± 15 ka; TL) Test A, Lev. 12 (166 ± 20 ka; ESR/LU) Test A, Lev. 19 (155 ± 21 ka; ESR/LU) Test A, Lev. 20 (186 ± 27 ka; ESR/LU ³)	
WHS 621	WHS	Middle Paleolithic Tabun B/C		
Tor Sadaf	WHNBS	Early Ahmarian Initial Upper Paleolithic		
Thalab al-Buhayra	EHLPP	Late Upper Paleolithic	Unit K3, Lev. 3 (25,680 ± 100) Unit B5, Lev. 4 (24,900 ± 130)	30,150–29,846 29,492–29,378; 2.4% 29,343–28,773; 93.1%
Ain al-Buhayra	WHS	Late Ahmarian	Test I, hearth, Lev. 2 (20,300 ± 600) E68/N42, Lev. 6 (20,670 ± 600) Hearth (23,500 ± 270)	25,826–23,138 26,289–23,726; 94.5% 23,543–23,425; 0.9% 28,307–27,246
WHS 623X	WHS	Upper Paleolithic (Ahmarian?)		
Yutil al-Hasa	WHS	Late Upper Paleolithic	Unit A, upper, Lev. 2A (19,000 ± 1300) Unit A, lower, Lev. 19 (22,790 ± 80)	26,447–20,160 27,300–22,6980
		Nebekian	Areas C and F	25,300–22,400
		Early Epipaleolithic		
		Early Natufian	Area D, lower (14,369 ± 290)	18,247–16,761
Tor Sageer	WHNBS	Late Upper Paleolithic	Unit D3, Lev. 7 (20,330 ± 60) Unit B3, hearth (20,840 ± 340) Unit B4, hearth (22,590 ± 80)	24,625–24,199 25,831–24,255 27,198–26,854; 67.1% 26,755–26,454; 28.4%
		Nebekian		
KPS-75	KPS/WHEEP	Nebekian Qalkhan Early Epipaleolithic		
Tor at-Tareeq	WHS	Qalkhan Nebekian Early Epipaleolithic Middle Epipaleolithic	Step A5 (16,900 ± 500) Step B4 (15,580 ± 250) Step B4 (15,860 ± 430) Area BIV (16,670 ± 270) Step C5 (16,570 ± 380) Step C5 (16,790 ± 340)	21,890–19,270 19,455–18,566; 83.3% 18,530–18,287; 12.2% 20,231–18,280 20,811–19,525 20,935–19,101 21,181–19,461
Tabaqa	WHS	Early Natufian		
TBAS 102	TBAS	Late Natufian	Unit 3, Lev. 3 (11,170 ± 70) Unit 4, Lev. 2 (11,040 ± 60)	13,231–13,211; 1.6% 13,183–12,903; 93.8% 13,095–12,830
TBAS 212	TBAS	Late Natufian	Unit 1, Lev. 4 (14,850 ± 60; shell)	18,271–17,999

¹WHS Wadi Hasa Survey, WHNBS Wadi Hasa North Bank Survey, EHLPP Eastern Hasa Late Paleolithic Project, KPS Kerak Plateau Survey, WHEEP Western Highlands Early Epipaleolithic Project, TBAS Tafia–Busayra Archeological Survey

²Calibration was conducted with OxCal v4.4 (Bronk Ramsey, 2021) using the IntCal20 database (Reimer et al., 2020)

³For a complete list of dates, see Clark et al., (1997, 91)

in Israel (e.g., Bar-Yosef, 2002; Boaretto et al., 2021; Gopher et al., 2010; Goring-Morris, 1995; Hovers & Marder, 1991).

The methodological approach advocated by Riel-Salvatore and Barton (2004) is applied to lithic assemblage datasets from west-central Jordan ranging from the Middle Paleolithic through the Late Epipaleolithic. As a first step, we plotted LVD vs. retouched percentage using a bootstrapped

95% confidence interval to get a sense of potential outliers in the dataset (e.g., assemblages that deviated from the cluster along one or more of the axes) (Fig. 3). In order to minimize the impact of outliers and reduce skewness in the data set, we followed their use of a log transform of the data for both of the axes (Riel-Salvatore & Barton, 2004:163). To offset the problem of logging a value of zero, a constant of 0.1

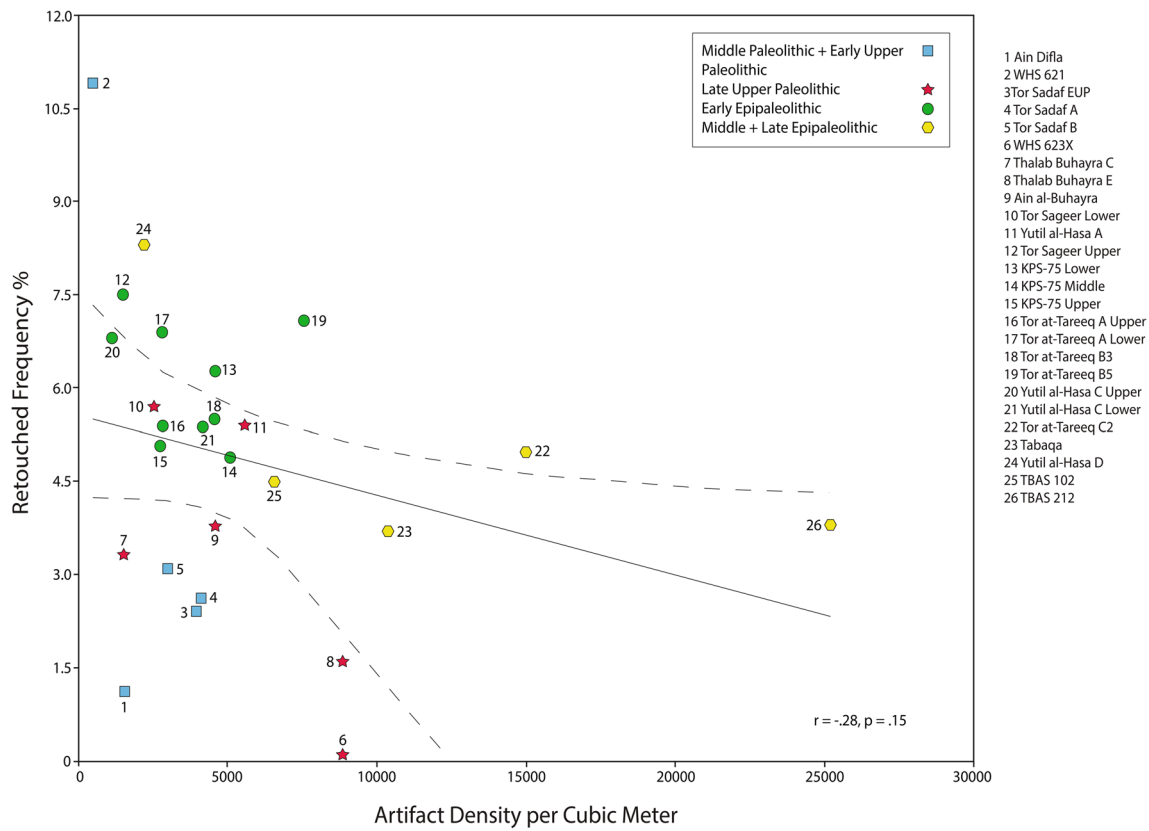


Fig. 3 Lithic volumetric density plotted against the relative frequency of retouched pieces for all of the Wadi Hasa sites in the study (13 sites, 26 levels). The dotted line represents a bootstrapped 95% confidence interval

was added to all the retouched percentage values. Finally, we used a bootstrapped 95% confidence interval around the logged regression line (Fig. 4). While several of the assemblages fall outside of the 95% confidence interval, we wanted to identify values that might be strongly influencing the regression line. To address this, we used Cook's distance, a measure that identifies data points with large residuals or leverage that impact the regression (Cook, 1977). This measure was applied to both the logged and unlogged data to see if there was consistency in the patterns (Fig. 5). Interpretations of significant Cook's distance values vary (Fox, 2020:51), but for the present purposes, we use the formula of $4/N$ as a cutoff (0.15 for our data). In the unlogged data plot, only one site (TBAS 212) has a high Cook's distance value (0.35). For the log-transformed plot, there are three sites (WHS 634 [Ain Difla], WHS 621, and WHS 623X) that exceed the 0.15 threshold. These are considered outliers.

Once identified, it is necessary to understand why they are outliers and what they might mean in terms of past behavior. Two of the assemblages, TBAS 212 and WHS 621, are outliers because they fall at the ends of the regression line. Behaviorally, they represent the ends of the curated-expedient continuum. In the case of WHS 621, the high retouched percentage along with a low LVD fits the expectations of the

model for a curated assemblage. The artifacts at WHS 621 were recovered from a deflated surface surrounding a fossil spring (Clark et al., 1987:21–31) and while clearly not in situ in the narrow sense of the term, show almost no indications of admixture with Upper Paleolithic assemblages, suggesting that the spring was no longer active after the Middle Paleolithic.

The other outlier is the Natufian site TBAS 212 which has an artifact density 1.67 times greater than the next closest site. This is an open-air site on a terrace, and it is likely that large, base camp occupations with very high artifact densities, may skew the trendline in the figure (see also Tor at-Tareeq C2 and Tabaqa). These assemblages appear to indicate greater expediency with high artifact frequencies associated with relatively low retouched percentages. The overall scatter plot confirms the inverse correlation between LVD and retouched pieces predicted by the model.

The remaining two outliers, Ain Difla, and WHS 623X, represent significant deviations from the regression line. Unlike TBAS 212 and WHS 621, which consist of outliers along the regression line, Ain Difla, and WHS 623X deviate from the regression line as observed in their high residual values (far greater than those of any other assemblages). We argue that these deviations are due to behavioral differences

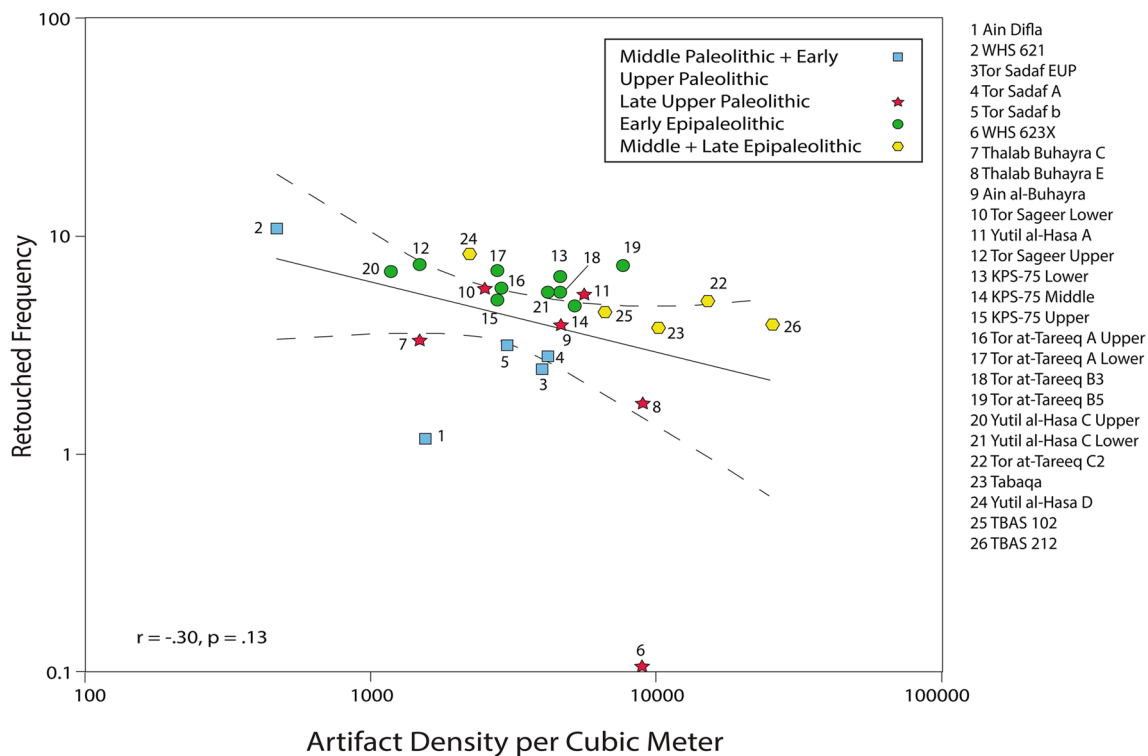


Fig. 4 Log of lithic volumetric density plotted against the log of the percentage of retouched pieces for all Wadi al-Hasa sites. The dotted line represents a bootstrapped 95% confidence interval

(WHS 623X) and issues of site preservation (Ain Difla) that are unique to these assemblages.

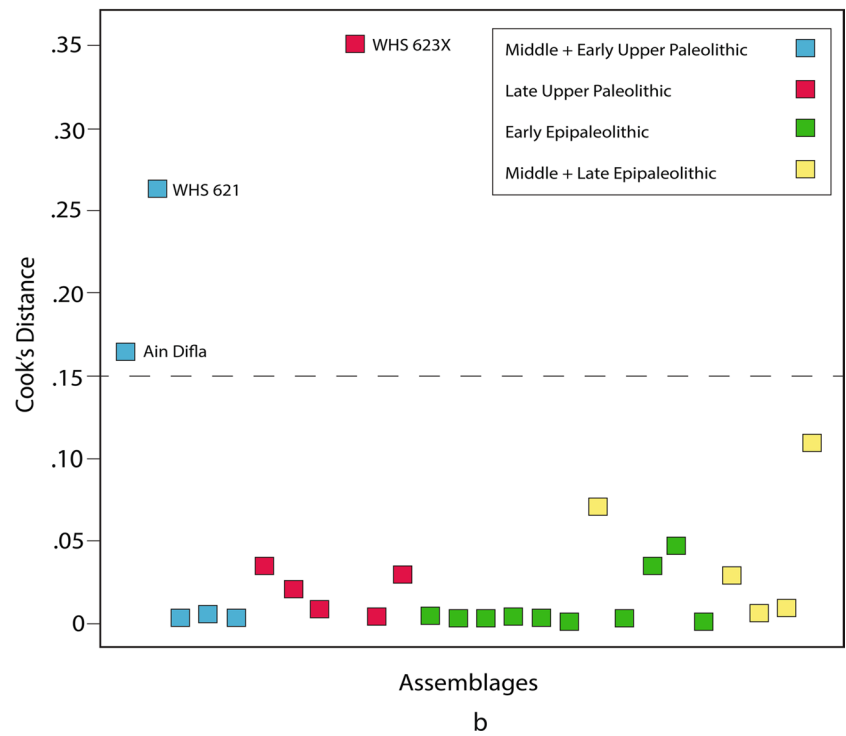
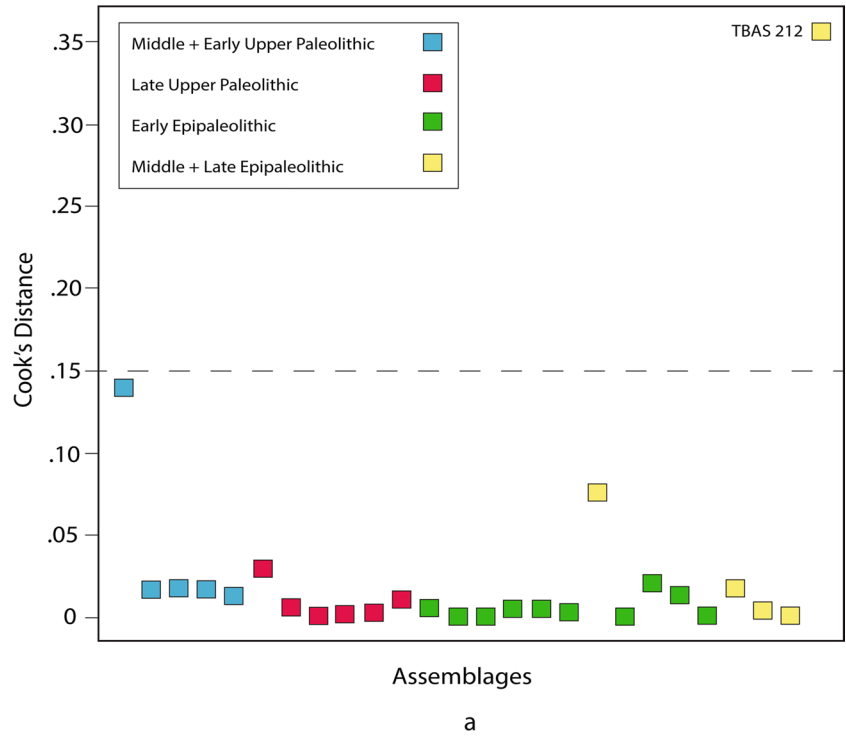
WHS 623X was a knapping station totally devoid of retouched pieces. Nine hundred sixty-seven lithics were recovered from an area of approximately 4 m² from the top 10–15 cm of sediment atop a marl knoll, probably accounting for approximately 99% of the lithics at the site. The collection included 11 refitted cores that showed specific reduction sequences—selection, removal of desired end-products (mostly blades), and discard—activities easily accomplished by one or two flintknappers over a period of c. 30–45 min. The shallow depth, refits, and spatial extent of WHS 623X all suggest minimal disturbance. The site was probably only recently exposed by aeolian erosion. “A moment frozen in time” about 23,000 years ago, WHS 623X is the only such site so far discovered in the wadi (Lindly et al., 2000).

The Ain Difla rock shelter was excavated in 1984, 1986, and 1992 (Clark et al., 1997). Lithics recovered from deep deposits comprised the greatest volumetric excavation in the study (12.45 m³). It yielded low values for both artifact density and retouched percentage. Complete cores recovered are few (0.9%), small, and mostly “exhausted”. Core types include Levallois point and flake cores and both single- and multiple- (opposed) platform flake, blade, and mixed (flake/blade) cores. The small

size of relatively complete cores in relation to the sizes of complete flakes and blades, the large number of core fragments, and the small trimming flakes suggest that most of the reduction sequence occurred at the site. The evidence for primary decortication is missing; although it should be kept in mind that “the site” is only a small, protected corner of a much larger rock shelter now emptied of fill by the meandering ancestral Wadi Ali (Clark et al., 1997; Lindly & Clark, 1987). Informal hearths consisting of reddish burned sediment in small, shallow, roughly oval depressions suggest that this part of the cave was only used ephemerally and for short periods of time, but the low incidence of retouched pieces per unit volume runs counter to the expectation, derived from the hearths, that curated assemblages would be found there. As a result, it might reflect recovery bias at the periphery of the site.

The marked differences of collections from Ain Difla and WHS 623X from the curated/expedient continuum model have led us to exclude these two assemblages from the subsequent analyses. We are of the opinion that the unique and unusual character of these two assemblages, while interesting in their own right, do not reflect the time-averaged, repeated use of places elsewhere in the Wadi al-Hasa landscape.

Fig. 5 Plot of Cook’s distance values by assemblage for **a** untransformed data and **b** log-transformed data



The Correlation Coefficient and Probability Statistic

For all plots, the correlation coefficient (*r*) is used to measure the strength of association of the points to a linear regression line based on those points and we provide probability statistics (*p*-values) that measure whether the correlation between

the variables is due to chance. We note that a correlation can be relatively weak (e.g., $r = \pm 0.45$) yet still statistically significant, depending on the probability associated with it (see Akoglu, 2018). The probability statistic is heavily influenced by sample size, so in cases of high correlation coefficients and small sample sizes, the associated *p*-value

may not be significant at the 0.05 level. Statistical methods for dealing with small sample sizes include permutation tests and bootstrapping. Both involve extensive resampling of the data set in order to gain greater confidence in its reliability (Berry et al., 2019; Efron & Tibshirani, 1993). Using the PAST statistical software (Hammer et al., 2001), we were able to run permutation tests of the p -values for the correlation coefficient. Variation between the standard and permutation p -values was minimal, ranging between 0 and 0.01, with little to no impact on the values. We have also tried to address the small sample size by combining temporal samples. This results in two groups consisting of a Middle and Upper Paleolithic sample on the one hand and an Epipaleolithic sample (Early, Middle/Late Epipaleolithic) on the other. These combined samples yield results that are statistically significant, yet the behavioral components of the smaller groups can still be discerned in the analysis.

All Assemblages

Data for all of the samples are given in Table 4. The corresponding plot (Fig. 6) shows a trend line that moderately supports the negative relationship between LVD and the retouched percentage expected by the model ($r = -0.46$, $p = 0.02$). While most of the assemblages are clustered together with LVDs $< 6000/\text{m}^3$, the assemblages range from more curated (upper left) to more expedient (lower right), suggesting variability in settlement and technological organization. Furthermore, the large number of assemblages in the middle probably reflects the time-averaged reuse of locations on the landscape as well as the general flexibility in settlement and technological strategies. While originally modeled as a relatively clear-cut bipolar opposition, and as long-indicated ethnographically (e.g., Owen, 1965), forager behavior is clearly more complicated and multidimensional, and likely includes elements of both technological strategies. Other complicating factors for unpacking settlement and technological organization might include duration of occupation, frequency of reoccupation, site function, seasonality, and resource procurement activities. Temporally, there appears to be quite a bit of overlap along the curated/expedient continuum, suggesting that over this long span of time, these foraging populations faced similar sorts of constraints and opportunities. The possible exception to this is the Middle/Late Epipaleolithic assemblages which are more closely associated with expedient organization along the lower right of the plot. This might reflect the first real shift in settlement organization associated with longer-term population aggregations associated with changing paleoclimatic (hence demographic) conditions favoring more residential stability, reduction in birth-spacing, and consequent increases in the rate of population growth beginning at the end of the

Pleistocene (e.g., Jones et al., 2016a, 2016b; Olszewski & Coinman, 1998).

Site Context: Rock shelter vs. Open-Air Sites

With two different kinds of occupation contexts (rock shelters and open sites), it is useful to examine the sites from each setting independently. The rationale is that site formation processes are likely to be very different between these two contexts. The underlying assumption is that open sites are more likely to be subject to deflation and erosional activities than rock shelters because the latter are potentially more protected from these processes. As a result, open-air assemblages might be expected to have higher artifact densities per unit volume than their rock shelter counterparts. This is exactly what we observe with the Wadi al-Hasa sample where the open-air sites have significantly greater artifact densities ($\bar{x} = 7513$, median = 5571) than do the rock shelter sites ($\bar{x} = 3378$, median = 3444) (Fig. 7). Explanations for the greater artifact density in open-air contexts could result from the aforementioned formation processes, but it also could entail underlying behavioral differences (i.e., structural poses). With greater artifact densities, open-air sites might more closely resemble the expectations for expedient assemblages, especially if retouched frequencies are significantly lower than rock shelter sites. On the other hand, if the artifact densities are more likely due to formation processes, then retouched frequencies should be similar between the two contexts. Figure 4 indicates that while rock shelters have slightly greater retouched percentages ($\bar{x} = 5.29$, median = 5.4) than the open-air sites ($\bar{x} = 5.12$, median = 4.75); this difference does not appear to be significant, lending support to the notion that formation processes may be largely responsible for the differences.

When we examine the plot of the rock shelter and open-air assemblages, they resemble the expected negative relationship of the model and contain moderate correlation coefficients (open-air, $r = -0.49$, $p = 0.10$; rock shelter, $r = -0.45$, $p = 0.13$) (Fig. 8). The lack of statistical significance suggests that the locational context of these sites had little impact on the strength of association with regard to the curated/expedient nature of these assemblages (Fig. 8). Other important factors potentially impacting these results include the number of assemblages sampled and the fact that these depositional contexts crosscut different technological traditions associated with the Middle Paleolithic, Upper Paleolithic, and Epipaleolithic. However, the open sites exhibit a greater range of values along the LVD axis suggesting that these sites encompass behaviors ranging along the curated/expedient continuum. In contrast, the rock shelter assemblages are more tightly clustered along the LVD axis suggesting a narrower range of behaviors associated with this variable. The more limited size or space of the rock

Table 4 Wadi al-Hasa data summary (13 Sites, 26 Levels)

Site	Site type ¹	C/S unit in analysis ²	Level and/or area	Total artifacts	Vol (m ³)	Artifact density	Ret'd pieces	Ret'd piece (%)	Reference
Ain Difla	R	MP+EUP		19,165	12.45	1539	211	1.1	Clark (2000)
WHS 621	O	MP+EUP		6090	13.1	464	662	10.9	Clark (2000)
Tor Sadaf	R	MP+EUP	EUP	14,114	3.6	3920	336	2.4	Fox (2003)
Tor Sadaf	R	MP+EUP	TSB	6236	2.1	2969	194	3.1	Fox (2003)
Tor Sadaf	R	MP+EUP	TSA	4732	1.15	4114	121	2.6	Fox (2003)
Thalab Buhayra	O	LUP	C	6720	4.5	1493	220	3.3	Coinman et al. (1999); Olszewski et al. (2001)
Thalab Buhayra	O	LUP	E	14,183	1.6	8864	226	1.6	Coinman et al. (1999); Olszewski et al. (2001)
WHS 623X	O	LUP		885	0.1	8850	0	0	Lindly et al. (2000)
Yutil al-Hasa	R	LUP	Area A	8307	1.5	5538	450	5.4	Olszewski (2003)
Ain al-Buhayra	O	LUP		16,424	3.6	4562	633	3.8	Olszewski (2003)
Tor Sageer	R	LUP	Lower	7528	3	2509	433	5.7	Olszewski (2003); Olszewski (2016)
Tor Sageer	R	Early Epi	Upper	5997	2.1	1482	438	7.5	Nahar and Olszewski (2016)
KPS-75	R	Early Epi	Lower	7706	1.4	4560	537	6.3	Nahar and Olszewski (2016)
KPS-75	R	Early Epi	Middle	5267	1.5	5085	487	4.9	Nahar and Olszewski (2016)
KPS-75	R	Early Epi	Upper	13,180	3.5	2792	1002	5.1	Nahar and Olszewski (2016)
Tor at-Tareeq	O	Early Epi	A upper	7715	1.5	2818	376	5.4	Nahar and Olszewski (2016)
Tor at-Tareeq	O	Early Epi	A lower	13,158	4	2755	845	6.9	Nahar and Olszewski (2016)
Tor at-Tareeq	O	Early Epi	B3	2694	0.6	4490	149	5.5	Neeley et al., (1998, 2000)
Tor at-Tareeq	O	Early Epi	B5	6060	0.8	7575	430	7.1	Neeley et al., (1998, 2000)
Yutil al-Hasa	R	Early Epi	C upper	7400	1.6	1160	455	6.8	Nahar and Olszewski (2016)
Yutil al-Hasa	R	Early Epi	C lower	5898	1.4	4212	316	5.4	Olszewski (2003)
Tor at-Tareeq	O	Middle Epi	C2	12,021	0.8	15,026	606	5.0	Neeley et al., (1998, 2000)
Tabaqa	O	Late Epi		7245	0.7	10,350	270	3.7	Olszewski (2013)

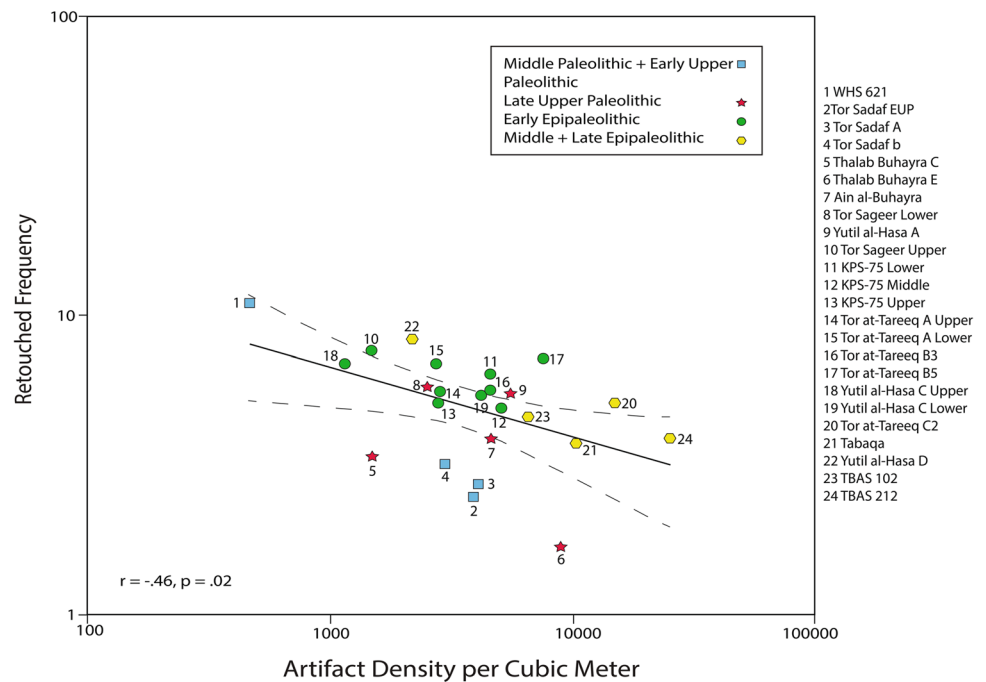
Table 4 (continued)

Site	Site type ¹	C/S unit in analysis ²	Level and/or area	Total artifacts	Vol (m ³)	Artifact density	Ret'd pieces	Ret'd piece (%)	Reference
Yutil al-Hasa	R	Late Epi	Area D	3626	1.65	2197	302	8.3	Olszewski (2013)
TBAS 102	O	Late Epi		9871	1.5	6580	449	4.5	Neeley (2013)
TBAS 212	O	Late Epi		22,663	0.9	25,181	869	3.8	Neeley (2013); Neeley and Hill (2017)
Mean (All)				9034	2.7	5426	423	4.8	
Mean (less Ain Difla and WHS 623X)				8951	2.4	5445	450	5.2	

¹R rock shelter, O open-air

²MP + EUP = Middle Paleolithic + Early Upper Paleolithic; LUP Late Upper Paleolithic; Early Epi Early Epipaleolithic; Middle Epi Middle Epipaleolithic; Late Epi Late Epipaleolithic

Fig. 6 Log of lithic volumetric density plotted against the log of the percentage of retouched pieces for the Wadi al-Hasa sites excluding WHS 634—Ain Difla and WHS 623X. The dotted line represents a bootstrapped 95% confidence interval



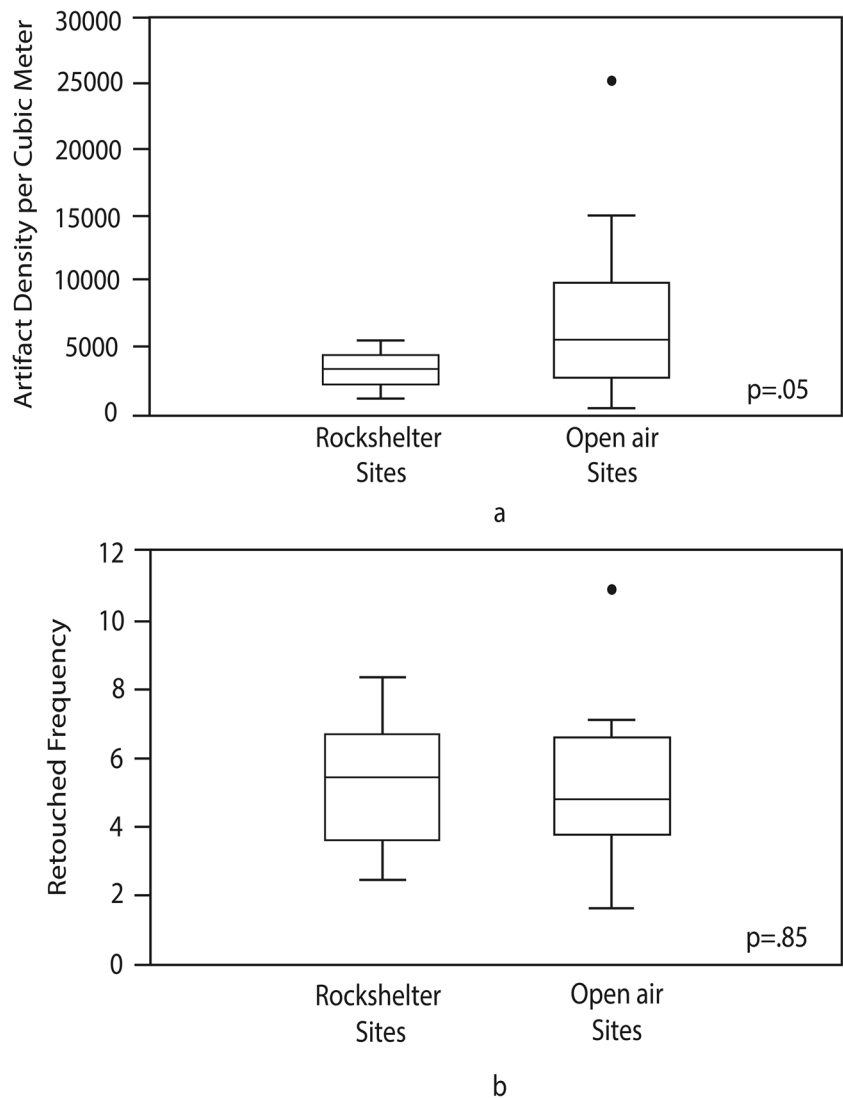
shelter contexts may result in shorter duration occupations and smaller group sizes associated with these assemblages. This behavior can be contrasted with reduced mobility and/or population aggregation associated with groups using more expedient technologies (e.g., the Natufian).

Temporal Patterns

In addition to the aggregated and context data, we also examined the scatter plots for temporal patterns corresponding to the major divisions of the Paleolithic and Epipaleolithic to determine whether, or to what extent, paleoclimatic change impacted how foragers organized or responded to changing

conditions. The temporal data are sorted into two groups: (1) Middle + Early Upper Paleolithic and Late Upper Paleolithic and (2) Early Epipaleolithic and Middle + Late Epipaleolithic/Natufian. It should be noted that the subsequent observations on climate are based primarily on research in coastal Israel and, to a lesser extent, Lebanon and Syria. Whether they can be extended inland to Transjordan is arguable. Until the 1990s, there was a broad consensus that most of the Middle Paleolithic was considered warm and wet, with a drying trend discernible only near the Middle/Upper Paleolithic transition. In contrast, the Upper Paleolithic was taken to be cool to cold and dry throughout, and the Epipaleolithic was characterized as having an unstable climate that extended

Fig. 7 Boxplot comparison of rock shelter and open-air sites. **a** Comparison based on artifact density per cubic meter and **b** comparison based on retouched frequency



into the early Holocene (Cordova, 2007). The accuracy of these climatic generalizations cannot fail to affect interpretations and correspondence to expectations about mobility patterns. At a gross analytical level, there appears to be little correspondence between the behavioral and paleoclimatic sequences.

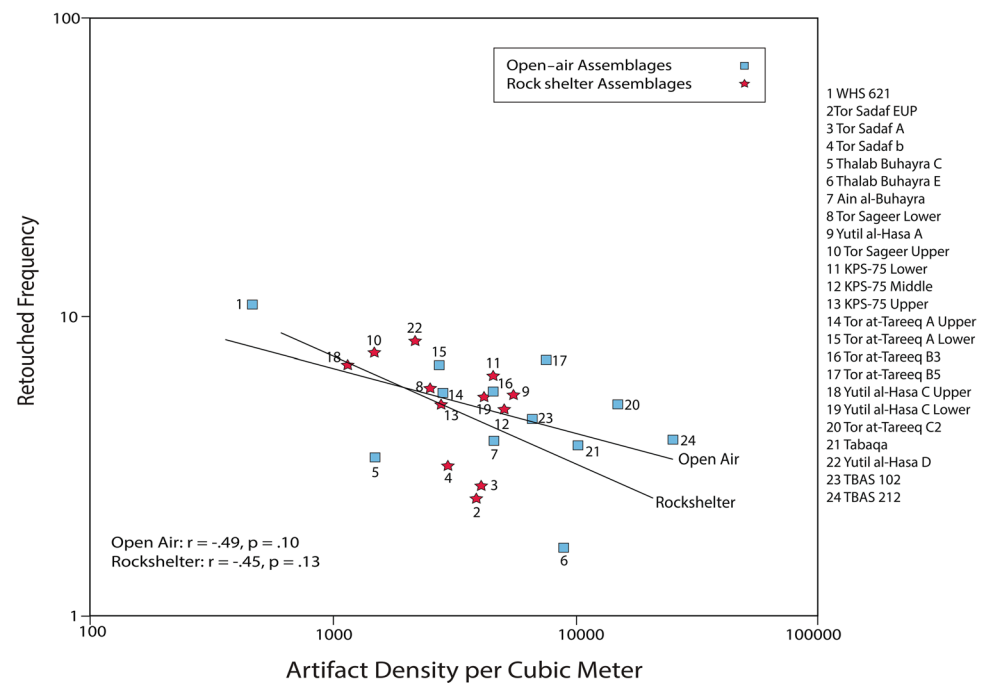
Middle Paleolithic and Upper Paleolithic

The Middle Paleolithic (~250 to 50 ka) spans oxygen isotope stages (OIS) 7–4 (242–57 ka). Although sometimes characterized as warm and wet throughout, it includes a significantly colder, drier episode of considerable duration (OIS 6, 186–127 ka) bracketed by OIS 7 (242–186 ka) and OIS 5 (127–71 ka) and extending into a second colder interval (OIS 4, 71–59 ka) (Klein 2009). In the older literature, radiating settlement systems with base camps were juxtaposed with limited activity stations. The former was defined

by high artifact densities but few tools relative to debitage, stratified deposits, midden formation, and the consistent use or re-use of space. The latter was equated with small camps, few artifacts, and features representing deployments of c. 2–6 individuals from the base camp for a day or two for particular purposes (e.g., raw material acquisition, hunting forays). Defined by two basic site types, these logistical strategies were attributed to optimal climatic conditions during the first half of the Middle Paleolithic followed by a drying trend during the second (e.g., Marks 1976, 1977, 1983).

The Upper Paleolithic, dated ~48 to 23 ka cal BP, basically coincides with OIS 3 (57–24 ka), considered a warmer, wetter period, at least so far as global OIS (or MIS) stages are concerned (e.g., Klein, 2009: 59). This is somewhat controversial in the Levant, however, because in the much-studied central Negev highlands (e.g., Marks 1976, 1977, 1983), there was a consensus that the Upper Paleolithic was overall cool to cold and dry, albeit interrupted by a relatively brief

Fig. 8 Log of lithic volumetric density plotted against the log of the percentage of retouched pieces for rock shelter and open-air sites



warmer, wetter interval (32–27 ka cal BP). The settlement pattern in the Negev is marked by a high degree of mobility with small groups of “circulating” foragers moving from one resource patch (esp. water) to another because of the increased importance of resource procurement scheduling in a more arid environment than that of the Middle Paleolithic. Sites are replicates of one another, blurring the distinction between residential bases and overnight camps. Although the sedimentary sequence has been well-studied (Dunseth et al., 2017), it cannot be correlated with the re-appearance of base camps, at least in the Central Negev Highlands.

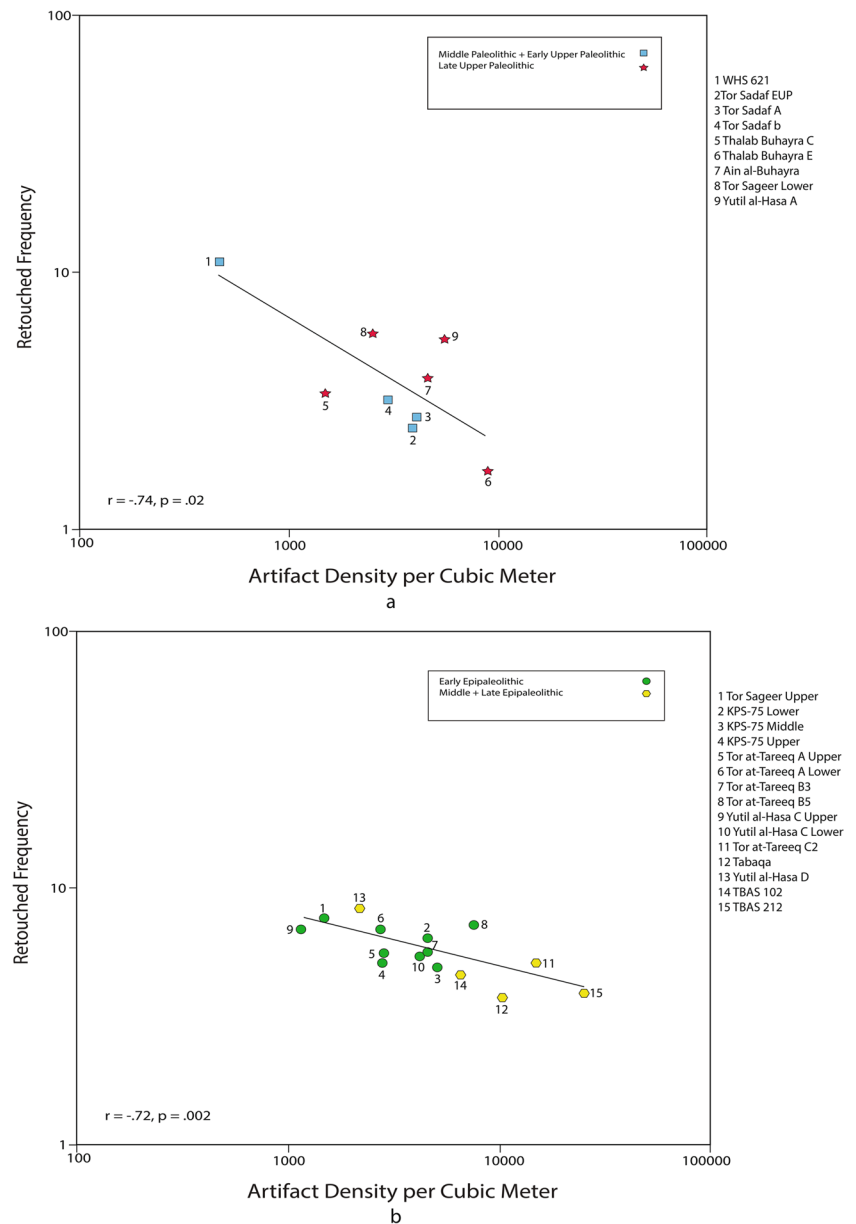
Taken together, the Middle Paleolithic and Upper Paleolithic sites exhibit a distribution that conforms to the expectations of the model with a strong correlation coefficient ($r = -0.74, p = 0.02$), in terms of which WHS 621 is clearly a “curated” assemblage (Fig. 9a). The site very likely indicates repeated visits to a source of freshwater by small groups of foragers detached from a larger residential base. Although deflated, collections derived from around the edges of a fossil spring approximated a 100% sample, no earlier or later material was recovered, tool stone (a fine-grained grey flint) is uniform, the artifacts were not weathered nor rolled, and the large number of small flakes and debris fragments coupled with the fresh, sharp appearance of the edges indicated minimal post-depositional disturbance. Therefore, while not in the primary context, it was concluded that the artifacts have not been moved very far from the locus of deposition (Clark et al., 1987: 23–31). Based on core and debitage characteristics, technological and typological indices, blank metrics, and palaeolandscape contexts, WHS 621 fits the consensus definition of a Tabūn

B/C industry (Bar-Yosef, 2000: 116–118), the first—to our knowledge—to be identified east of the Jordan (although see Hauck (2010)). As the sole Middle Paleolithic assemblage, it falls on the curated end of the continuum and lends support to the notion that at least some of the behavioral expectations of Middle Paleolithic radiating settlement (e.g., ephemeral task-oriented sites) can be found within the Wadi al-Hasa region.

The three Early Upper Paleolithic levels are all from Tor Sadaf, a rock shelter with an in situ transition from the late Middle to the Early Upper Paleolithic (Coinman, 1990, 2003; Fox, 2003). These assemblages are tightly clustered at the center of the diagram and probably reflect very similar kinds of behaviors along the curated/expedient continuum. Interestingly, when the Tor Sadaf assemblages are placed in the context of all of the assemblages, they tend to be lower in the scatter closer to the Late Upper Paleolithic assemblages. These are generally characterized by lower percentages of retouched pieces relative to artifact density and thus reflect a relatively more expedient assemblage.

The Late Upper Paleolithic is represented by five assemblages comprising both rock shelter and open-air occupations (Fig. 9a). Two of the assemblages (Tor Sageer Lower and Thalab Buhayra C) are at the upper end of the cluster, potentially closer to the expectations for curated behavior, whereas Thalab Buhayra E is indicative of a relatively expedient assemblage. This distribution is also reflected in the larger, aggregated data set. It is worth noting that most of the Middle and Upper Paleolithic assemblages (67%) fall below the regression line in the aggregated figure (Fig. 6), largely due to the lower relative frequencies of

Fig. 9 Log of lithic volumetric density plotted against the log of the percentage of retouched pieces. **a** Middle Paleolithic + Early Upper Paleolithic and Late Upper Paleolithic sites and **b** Early Epipaleolithic and Middle and Late Epipaleolithic sites



retouched pieces in these assemblages. Median retouched percentages for the Middle + Early Upper Paleolithic and Late Upper Paleolithic (3.3) are lower than the Early Epipaleolithic and the Middle + Late Epipaleolithic (5.5). While this trend is reflected in the numbers, we cannot rule out the expedient use of sharp edges that are not identified as formal tools occurring in these assemblages. Also, technological aspects of reduction emphasizing larger flakes, blades, and bladelets might yield usable pieces that do not require extensive modification or, indeed, any modification at all. In contrast, the microlith-dominated industries of the Epipaleolithic, derived from smaller raw material packages, might have rendered such an emphasis on expedient tools no longer practical.

Overall, the Middle and Upper Paleolithic assemblages exhibit variability along the curated/expedient continuum, and the blurring of patterns associated with circulating settlement documented by Marks in the Upper Paleolithic is not supported by the Hasa data. Rather, a range of settlement types from curated to expedient can be found among these assemblages. This implies that associated paleoenvironmental change was not overwhelming pattern in the archeological record of the Hasa.

The Early, Middle, and Late Epipaleolithic

Beginning at the onset of the LGM, the Epipaleolithic (~23 to 11.7 ka cal BP) ends at the Pleistocene–Holocene

boundary. It coincides almost exactly with OIS 2 (24–11 ka), a cooler period overall but marked by a warmer, wetter episode in its latest phase, the Early Natufian (14.6–13 ka cal BP), with a return to cooler conditions associated with the Younger Dryas in the Late Natufian (13–11.7 ka cal BP). In general, all Epipaleolithic industries are dominated by microliths—bladelets set into slots in organic hafts to make projectiles, sickles, and knives. Except insofar as they are “tethered” to reliable water sources (springs), the standard model for the Epipaleolithic in the xeric regions of the Levant is one of small groups of foragers moving seasonally from patch-to-patch accessing resources as they become available in the environment or until the cost/benefit ratio of exploiting them makes moving a better strategy than staying put. The Early Natufian is distinct from the earlier Epipaleolithic because of evidence for sedentism and precocious social complexity, including the appearance of substantial architecture and permanently occupied pre-agricultural villages. These elements are largely absent from the subsequent Late Natufian with a few exceptions (e.g., Nahal Ein Gev II [Grosman et al., 2016]). The Late Natufian is followed by the earliest evidence for domestication economies in the Pre-Pottery Neolithic (PPN), dated to ~ 11.7 to 8.2 ka cal BP (Peterson, 2017).

The Epipaleolithic in the Wadi al-Hasa is represented by 15 assemblages from seven sites ($r = -0.72$, $p = 0.002$) mostly spread along the curated/expedient continuum (Fig. 9b). These assemblages represent a range of forager behaviors and include some of the best examples of expedient technological organization in the Wadi al-Hasa sample. In comparison to the Late Upper Paleolithic, the Early Epipaleolithic average artifact density is slightly lower ($\bar{x} = 4593$ vs. $\bar{x} = 3692$), but the percentage of retouched pieces is generally higher ($\bar{x} = 3.9$ vs. $\bar{x} = 6.0$). The higher percentage of retouched pieces is likely a reflection of the emphasis on bladelet production for use in various composite tools. The Early Epipaleolithic sample differs from the others as retouched percentages are much more tightly grouped regardless of the LVD values. This might reflect a narrower range of activities and/or settlements over time corresponding to an Early Epipaleolithic settlement model of generally high residential mobility.

The Middle + Late Epipaleolithic sample is represented by five sites of which four are representative of the Natufian (Early and Late phase) and one assemblage (Tor at-Tareeq C2) assigned to the Middle Epipaleolithic based on typological characteristics (Olszewski, 2000). Given that climatic conditions during the Middle Epipaleolithic (17.5–14.6 ka cal BP) were likely warmer and wetter than the preceding Early Epipaleolithic, we combine this assemblage with the Late Epipaleolithic group. The assemblage from Tor at-Tareeq C2 contains relatively high artifact densities and better fits the expectations for an expedient

assemblage. Similar sorts of high-density and sedentary behaviors have been suggested for other Middle Epipaleolithic sites like Kharaneh IV and Jilat 6 in eastern Jordan (Maher et al., 2012).

There is a vast literature on the Natufian, mainly concerned with the evidence for sedentism and social complexity when compared with the earlier Epipaleolithic (see Valla 2018 for a historical overview). It extends back to the 1930s when Dorothy Garrod coined the term (Garrod, 1932) up to the present (e.g., Weinstein-Evron et al., 2012; Yeshurun et al., 2014). Natufian sites are widely distributed in the figure and appear to encompass both curated (Yutil al-Hasa [WHS 784]) and expedient (TBAS 212, Tabaqa) assemblages. The average artifact density for Natufian sites is nearly double that of both the Late Upper Paleolithic and the Early Epipaleolithic suggesting that, in accord with the generally accepted greater sedentism of the Early Natufian (e.g., Valla, 2018), these assemblages tend toward the expedient end of the distribution in the aggregated plot. Except for Area D at Yutil al-Hasa, a collapsed rock shelter, all the Natufian sites are open-air occupations. The higher densities probably reflect a combination of increased sedentism, repeated occupation, and larger social group size that is generally associated with many Natufian sites in Israel (e.g., Bar-Yosef, 2002; Belfer-Cohen, 1991; see Olszewski, 2011; Yeshurun et al., 2014 for overviews).

Regarding settlement and paleoenvironments, the Early Epipaleolithic, while representing behaviors on the curated/expedient spectrum, tends to be closely bunched together. We take this to potentially reflect the presence of small groups regularly reusing locations on the Wadi al-Hasa landscape. These assemblages do not reflect the extremes of the curated/expedient continuum. The Middle/Late Epipaleolithic distribution appears to represent a significant shift toward more expedient technologies with multiple sites at the end of the continuum. In addition to the clustering at the expedient end, there is an assemblage at the curated end (Yutil al-Hasa D), suggesting that with the transition to more mesic conditions, the pattern of settlement and land use changed as well (Olszewski, 2013; al-Nahar & Olszewski, 2016).

Interpretation and Concluding Remarks

So what can we say about these data and their fit to the model? In the general graph (Fig. 6), the overall pattern supports the model. Regardless of time and context, most sites are clustered in the middle-right part of the graph, thus indicating a predominance of mixed assemblages but with only moderate retouched frequencies, LVDs of < 6000, and $r = -0.46$. This is not entirely unexpected given the xeric, “resource patchy” environment of the eastern Hasa—one

that would favor high mobility and relatively more curated assemblages over the long term. Truly expedient assemblages appear to be rare and would be confined to favorable locations or time periods (e.g., availability and proximity to water or springs) when more mesic conditions supported reduced mobility. Support for higher residential mobility and greater curated strategies can be found in the study of Early Epipaleolithic faunal assemblages from the region (Munro et al., 2016). A striking aspect of Fig. 6 is the concentration of higher retouch in the Epipaleolithic sample, probably due to a high incidence of retouched bladelets. Nearly all (86%) of the Early, Middle, and Late Epipaleolithic sites/levels fall above or on the regression line, a trend that supports the notion of greater retouched frequency in these assemblages. The higher frequency of retouching can be impacted by the different ways researchers count retouched bladelets in their tool counts (e.g., only complete microliths vs. complete + fragmentary microliths).

When the data are segregated by time and the paleoclimatic record, a number of trends emerge. The Middle Paleolithic/Early Upper Paleolithic sites range from curated (WHS 621) to relatively more expedient (Tor Sadaf—see Coinman, 2009; Fox & Coinman, 2004). This distribution offers support to the expected pattern of climatically influenced land-use patterns associated with greater expediency along with the presence of logistically organized sites during the Middle Paleolithic. However, the sample size is small, and additional Middle Paleolithic assemblages would better support this conclusion. A limiting factor to identifying short-term encampments like WHS 621 has to do with their low archeological visibility and their research potential for selective excavation. Were it not for the spring and the repeated visits over the long term, WHS 621 would have been archeologically “invisible”. Furthermore, sites in open-air contexts within the Wadi al-Hasa have been subject to long-term geomorphological processes that have removed or substantially altered the ancient landforms upon which these sites were situated (Schuldenrein & Clark, 2001, 2003).

Patterning in the Late Upper Paleolithic is less clear with one site (Thalab Buhayra E) further on the expedient spectrum than the other sites. While this suggests differences in settlement organization relative to the expectations of the older Negev paleoclimatic models, the sample size is small and probably reflects continuous rather than discrete variation in settlement behavior and site use. The Early Epipaleolithic distribution is the most homogeneous; it appears to conform to the unstable climatic conditions that favored similar sorts of settlement strategies. The sites we examined tend to cluster in the center of the plots (Figs. 6 and 9).

Finally, the Middle + Late Epipaleolithic sites show a good fit with the expected settlement patterns associated with the paleoclimatic data. Large, high-density expedient assemblages (e.g., Tabaqa, TBAS 212, Tor at-Tareeq C2)

contrast with curated assemblages (Yutil al-Hasa D) in what might be the material correlates of a relatively complete settlement/subsistence system. While these later sites appear to stand out in comparison to the earlier time frames, it is worth considering whether the potential residential bases in the Middle Paleolithic, Upper Paleolithic, and Early Epipaleolithic would be comparable to the Late Epipaleolithic in terms of LVD. Given the emerging sedentism and changes in social organization associated with the latter, the residential cohort might be significantly larger than in the earlier time frames, thus obscuring the expedient organization that is part of the settlement strategy.

It is well-documented that most of the sites in the eastern third of the drainage are associated with weakly alkaline, shallow lakes ringed by freshwater swamps fed by springs that attracted both humans and the fauna upon which they preyed (mainly gazelle). As exemplified here by WHS 621 and documented by MacDonald’s surveys south of the Hasa (MacDonald et al., 2004, 2012, 2016), these springs came and went over the course of millennia as a consequence of changes in the local hydrology. At a relatively fine-grained scale, the regional picture differs markedly from that of the macroclimatic changes documented by MIS/OIS chronologies. Insofar as Fig. 6 is dominated by sites dated to the early and late phases of the Epipaleolithic (~23 to 11.7 ka cal BP), this suggests that locally, at least, this interval was characterized by recharging of aquifers and more spring activation relative to the Late Upper Paleolithic.

What can we conclude from this? As an exploratory tool, the ratio of retouched pieces relative to LVD has some utility in potentially explaining or helping us to understand the sources of variation in lithic assemblages. However, as noted by others (Barton & Riel-Salvatore, 2014; Riel-Salvatore & Barton, 2004), this is just a first step toward understanding this variability. A more thorough understanding of each site in terms of the processes of site formation, the site functional activities, and larger land-use strategies is necessary before we can apply this model as a means of explanation. In particular, what are the conditions or processes of site formation and how might these alter the position of sites relative to the expectations of the model? How do different behavioral activities impact the values generated in the model? And what is the basis for our initial assumptions about site function within a settlement system (i.e., are we just relying upon site size or artifact density without understanding how these might be influenced by site formation processes?). We suggest that the ultimate utility of this model relies upon a greater understanding of exogenous factors and how they square with the model expectations associated with curated and expedient technologies. While these variables result in an impressionistic understanding of prehistoric settlement organization, the more standardized approach advocated by Riel-Salvatore and Barton (2004) has the potential to

separate some of the different elements of settlement behavior. Traditional interpretations, spanning the Upper Pleistocene and early Holocene have generally emphasized high levels of residential mobility for the Upper Paleolithic and Epipaleolithic and more logistical organization in the Middle and Late Epipaleolithic. Our results tend to bear this out and indicate the utility of this curated/expedient model as a starting point. However, site formation processes, site functional activities, and the WABI approach within landscape-scale settlement systems must be better understood to enhance and expand its interpretative potential.

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Data Availability The authors confirm that all of the data analyzed during the study are included in this published article.

Declarations

Ethics Approval and Consent to Participate Not Applicable.

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