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2016
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Biagetti, S., Alcaina-Mateos, J. and Crema, E.R. 2016. A matter of ephemerality: The study of Kel Tadrart Tuareg (southwest Libya) campsites via quantitative spatial analysis. Ecology and Society 21(1):42.

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Biagetti, S., J. Alcaina-Mateos, and E. R. Crema. 2016. A matter of ephemerality: the study of Kel Tadrart Tuareg (southwest Libya) campsites via quantitative spatial analysis. *Ecology and Society* 21(1):42. http://dx.doi.org/10.5751/ES-08202-210142

Research, part of a Special Feature on Small-Scale Societies and Environmental Transformations: Co-evolutionary Dynamics

A matter of ephemerality: the study of Kel Tadrart Tuareg (southwest Libya) campsites via quantitative spatial analysis

Stefano Biagetti [1,2,3], *Jonas Alcaina-Mateos* [1,2,4] *and Enrico R. Crema* [1,2,5]

ABSTRACT. We examined the settlement structure from the Kel Tadrart Tuareg, a small pastoral society from southwest Libya. Our objective was to apply spatial analysis to establish the statistical significance of specific patterns in the settlement layout. In particular, we examined whether there is a separation between domestic and livestock spaces, and whether particular residential features dedicated to guests are spatially isolated. We used both established statistical techniques and newly developed bespoke analyses to test our hypotheses, and then discuss the results in the light of possible applications to other case studies.

Key Words: *campsites; Kel Tadrart Tuareg; settlement layout; spatial analysis*

INTRODUCTION

The study of pastoral settlements has traditionally held a problematic position in the archaeological literature. Allegedly invisible and likely impermanent, nomadic campsites have challenged generations of archaeologists and a variety of methodological and theoretical approaches. The ephemeral nature of their structural remains in fact limits our capacity to identify settlement layouts and ultimately the reconstruction of the past use of space, whether this is the overall extent of the area where daily activities where performed or the identification of specific spatial patterning of the build environment.

In the study of ancient pastoral societies, the observation of modern living populations has traditionally played a central role. Indeed, ethnoarchaeology has focused on current pastoral campsites to develop strategies for ancient sites' identification and interpretation. In the domain of settlement pattern, the unique possibility of directly observing human behavior and its material correlates places ethnoarchaeology in a optimal position for shaping a more complete and comprehensive vision of ancient settlements. Scholars have explored the settlement behavior of pastoral nomads in different contexts, showing that material evidence can be indeed detected in the archaeological record. Architectural remains, activity areas, artifacts, and recognizable alterations of the natural environment have been reported in a variety of case studies (e.g., David 1971, Robbins 1973, Gifford 1978, Robertshaw 1978, Hole 1979, Cribb 1991, Avni 1992, Banning and Köhler-Rollefson 1992, Bradley 1992, Palmer et al. 2007, Saidel 2009). Although most of this research was problem oriented, context specific, and archaeologically raised, a variety of middle-range theories have been extrapolated from these particular case studies to approach the study of the vestigial remains of past societies.

We examined the settlement layout of the Kel Tadrart Tuareg. This small-scale society from southwest Libya offers an exceptional context for studying the settlement layout of mobile pastoral communities. In particular, we investigated whether there is a separation between domestic and livestock spaces, and whether particular residential features dedicated to guests are spatially isolated. All analyses were performed using the R statistical programming language (R Development Core Team 2014), with the spatstat (Baddeley and Turner 2005), maptools (Bivand and Lewin-Koh 2015), and rgdal libraries (Bivand et al 2014). The source code, scripts, and data set can be found at zenodo (http://dx.doi.org/10.5281/zenodo.45453).

IN THE SAHARA: THE KEL TADRART TUAREG OF THE ACACUS MOUNTAINS

Pastoralism is a widespread strategy in arid lands that is well adapted to cope with erratic rainfall and patchy resources. In the Sahara, the earliest evidence of animal husbandry is dated to about 7000 years ago, three millennia before the adoption of agriculture (di Lernia 2013 and references therein). Its ideological and socioeconomic role remained central even after the spread of farming, and its primacy is well reflected by its relevance in the research agenda of Saharan subsistence archaeology (e.g., Dunne et al. 2012). Most of the Holocene archaeological sites within this region are indeed pastoral settlements, set either in caves and rock shelters or in open-air locations (e.g., Biagetti and di Lernia 2013). Despite the long-term continuity of this subsistence strategy, which persists to the present day, a considerable lack of ethnoarchaeological research hinders the comparison between the past and the present in the Sahara.

The Kel Tadrart are a small lineage of pastoral Tuareg living in the Tadrart Acacus mountains, located in the southwest corner of Libya (Fig. 1). They raise goats, sheep, and dromedaries, but they are also involved in a range of subsidiary activities, including wage work, service in the army or police, and until 2011, tourism. They recently were the subjects of a specific ethnoarchaeological research project run between 2003 and 2011 (Biagetti 2014*a*, 2015, *in press*, Biagetti and Chalcraft 2012). Kel Tadrart society is based upon a small number of households, generally composed of three generations (elders, adults, and unmarried children; Table 1), with their heads being closely related, generally siblings or first cousins. The Kel Tadrart settlement pattern is generally driven by pasture availability, the water being easily transported from the wells of the *gueltas* (rock pools). Different patterns of mobility have been recorded, from full sedentism to regular transhumance, with the majority of the households having opportunistic and flexible strategies for residential moves, and individual choices overriding

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fixed schemes of transhumances. At the site level, an unexpected variability in domestic architecture has been explained from an historical perspective. The use of plant material has been in fact linked to the adoption of an original wooden prototype, identified by the Kel Tadrart as "their" hut, whereas stone huts are considered a late adoption. The study of a set of recently abandoned campsites has given some time depth to the observations collected in the present, showing evidence of "delayed curation" (Tomka 1993), whereby previous inhabitants repeatedly visit abandoned campsites collecting usable items and leaving worn ones. The accumulation of these activities over multiple years generally leads to the deprivation of small items, with the exception of broken artifacts and, crucially, most of the dwellings.

Fig. 1. The study area: red dots indicate the the Kel Tadrart main campsites.

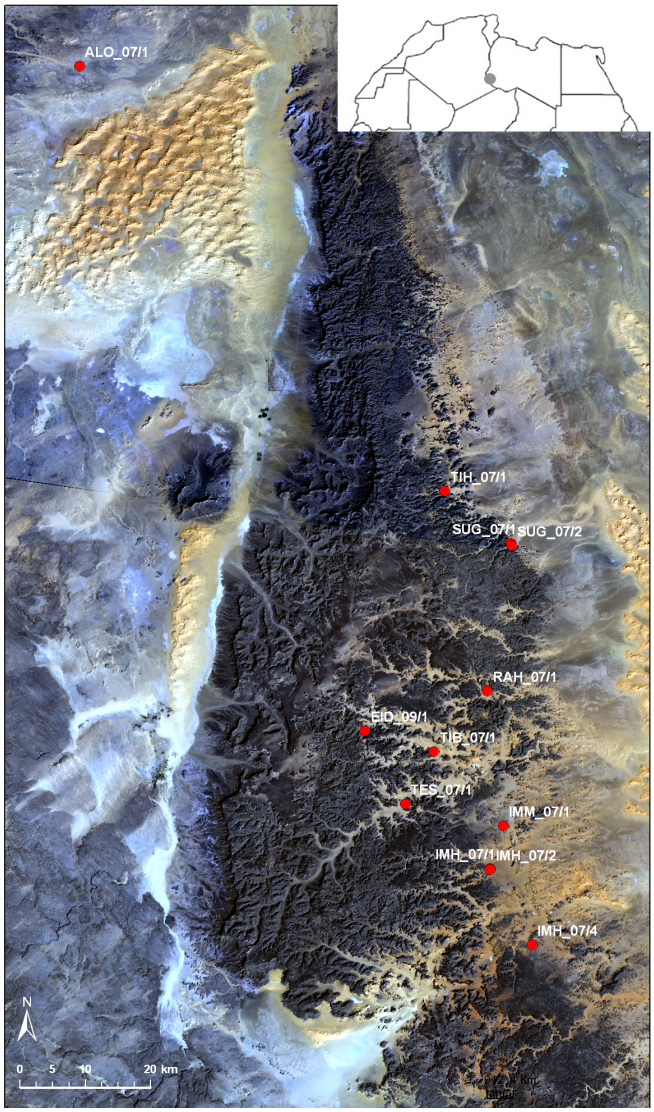


Table 1. The Kel Tadrart main sites (2007-2009), with number of inhabitants and livestock.

Site	Inhabitants	Sheep/goats	Camels
ALO_07/1	4	80	
IMH_07/1	3	80	
IMH_07/3	5	90	
IMH_07/4	5	70	
EID_09/1[†]	5	90	
IMM_07/1	7	130	9
RAH_07/1	4	90	3
SUG_07/1	9	60	
SUG_07/2	4	40	
TES_07/1	4	110	5
TIB_07/1	6	130	4
TIH_07/1	8	230	
total	64	1200	21

[†]The only main settlement (EID_09/1) that was not mapped and was not included in the present study.

This particularistic research has provided insights on the ability of the Kel Tadrart to adapt, through a diversification of their activities, to a hyperarid environment. This diversification does leave traces on the ground, the study of which allows exploring the nuances of this successful human adaptation to extreme environments.

THE KEL TADRART SETTLEMENTS: MATERIAL AND METHODS

We examined the main settlements of the Kel Tadrart, i.e., those where their households spend most of time of the year and are emically defined as primary residential sites (Table 1). Our data set consists of all main settlements previously recorded (Biagetti 2014*a*, Table 3.3), which correspond to all Kel Tadrart primary residential sites but one (EID_09/1 was not examined for logistical reasons), dated between 2003 and 2009 (n = 11). We excluded from our analysis all secondary and opportunistic campsites, generally occupied for a shorter interval, that dot the Tadrart Acacus landscape (Biagetti 2014*b*).

In broad terms, the absolute locations of Kel Tadrart main settlements are strongly determined by the local topography. Campsites are located on flat tops slightly raised above *wadi* floors with some distance from dry riverbeds to prevent damage in case of floods. Features are often built in proximity to rocky flanks or outcrops to protect the settlers and the livestock from the cold winter winds and, at the same, offer shadow and structural support; boulders, niches, and vertical rock walls are often incorporated in the architectural features.

We deliberately focused on permanent features, generally made of wood, straw, and stones, and left aside small, movable objects. This is not to deny the usefulness of the research on small items, especially from an ethnoarchaeological perspective. However, the research so far carried out among the Kel Tadrart (Biagetti 2014*b*) included the processes of the abandonment of settlements, demonstrating that within deserted sites a mechanism of delayed curation (sensu Tomka 1993) operates.

Architectural features of Kel Tadrart settlements can be broadly grouped in two categories on the basis of their primary use: domestic features for daily-life purposes (sleeping, cooking, etc.) and facilities apt for husbandry (Table 2). Typically the former include nonmovable fixtures such as dwelling huts, one or two kitchens, occasionally one wood-made garage, stores, normally the *diwan* (a special purpose hut for hosting guests), stone-lined mosques, and a variety of other features such as dumps, wood piles, and fuel barrels. Livestock features include a stone pen for newborns, a few barbed wire corrals, a few chicken houses, and dung areas. Occasionally, Kel Tadrart campsites include also two or more isolated features set at a considerable distance from the others. This peculiar configuration is because of the presence of unmarried adult sons (daughters are encouraged to marry at a relatively young age) who deliberately set their hut and other associated features aside from their parents' hut. Despite their isolation, they still gravitate around their parents and still collaborate with them in the herd management and other daily duties. All the campsites' features were mapped by taking a single point in their centroid using a hand-held global positioning system (Fig. 2)

Table 2. Number of domestic and livestock features at Kel Tadrart campsites, features belonging to unmarried offspring, and the presence or absence of the *diwan* (as in 2007). Site SUG_07/1 (†) features some structures that were declared to belong to unmarried offspring who were not present at the time of the visit by one of the authors (SB); thus, data regarding use and ownership were not directly collected, as they were in other cases.

Settlement	Domestic features	Livestock features	Domestic features for unmarried offspring	Livestock features for unmarried offspring	*Diwan*
ALO_07/1	8	6	2	0	0
IMH_07/1	11	2	2	0	1
IMH_07/3	11	8	0	0	1
IMH_07/4	10	6	0	0	1
IMM_07/1	12	4	2	0	1
RAH_07/1	19	5	3	0	1
SUG_07/1†	9	3	4	0	0
SUG_07/2	12	4	0	0	1
TES_07/1	21	3	6	0	1
TIB_07/1	10	3	0	0	0
TIH_07/1	14	6	3	1	1

Although the small scale of these pastoral communities does not ensure a sufficient sample size for statistical analysis at the level of individual sites, the aggregate data offer an exceptional basis for investigating the spatial layout of these campsites in general. Interviews with members of each site provided us with key knowledge that can be hardly recovered from archaeological contexts, such as the function and use of a given feature and its ownership by a specific household.

We contribute to the broader ethnoarchaeological research agenda on the human use of space by examining two social and functional hypotheses of Kel Tadrart settlement layouts: (1) the spatial segregation of domestic and livestock features and (2) the isolation of special-purpose huts (*diwans*) apt for hosting guests.

Fig. 2. The campsite SUG_07/1. The abbreviation "sup. st." indicates superelevated store.



The first hypothesis was originally proposed by Biagetti (2014*c*) in his ethnoarchaeological study of the Kel Tadrart. Although the hypothesis was never formally tested, the recorded data from the campsites suggested that the cohabitation of humans and livestock was within defined spaces, from which emerged spatially segregated areas to be exclusively used either by animals (e.g., pens, corrals, dung areas) or by humans (huts, kitchens, dumps).

One possible hypothesis that may explain the supposed isolation of *diwans* is the specific attitude of avoidance that is widely observed in the Tuareg world. Modesty and discretion, along with hospitality, are extremely important values among the Tuareg (e.g., Gast 1968, Rasmussen 1998, Camps-Fabrer 2000). Nicolaisen and Nicolaisen (1997) provide an excellent account on the typical behavior of hosts and guests. They note that host behaves with the utmost reserve and care, and anyone who plans to visit someone's else campsite will try to dress in the finest clothes, veiling his or her face to the most, talking carefully and modestly, and trying not to seek attention. This seclusive behavior is observed among both strangers and relatives during a visit and can be regarded as a key social element that is considered when a new settlement is build. Given the special use of *diwan* as the hut where adult men gather for discussing political and social issues, as well as the place were these occasional guests are invited to stay overnight, we should expect to observe some differences in *diwans'* structural properties and their spatial location. Although the former does not seem the case (Kel Tadrart *diwans* are architecturally identical to other dwelling huts but differ in their mobile furniture), the latter is suggested by the visual impression of existing settlement layouts. We statistically analyzed this, in particular looking at the isolation of *diwans* in respect to other domestic features of the same settlement.

The size of the campsites

Objective estimates of the extent of Kel Tadrart campsites are hard to retrieve. Although information regarding the presence of each feature in one household or another can be retrieved directly from interviews with the local residents, a precise emic definition of the areal extent of each campsite does not exist. We overcame this limitation by using a technique called the Ripley-Rasson estimate (Ripley and Rasson 1977), which is used in the field of point process analysis, a branch of spatial statistics apt to study the spatial

arrangements of objects that can be represented as points. Point process analysis has recently seen a steady rise of applications in archaeology (see Bevan et al. 2013 for a review), offering ways to test and compare a broad range of hypotheses (e.g., see Eve and Crema 2014).

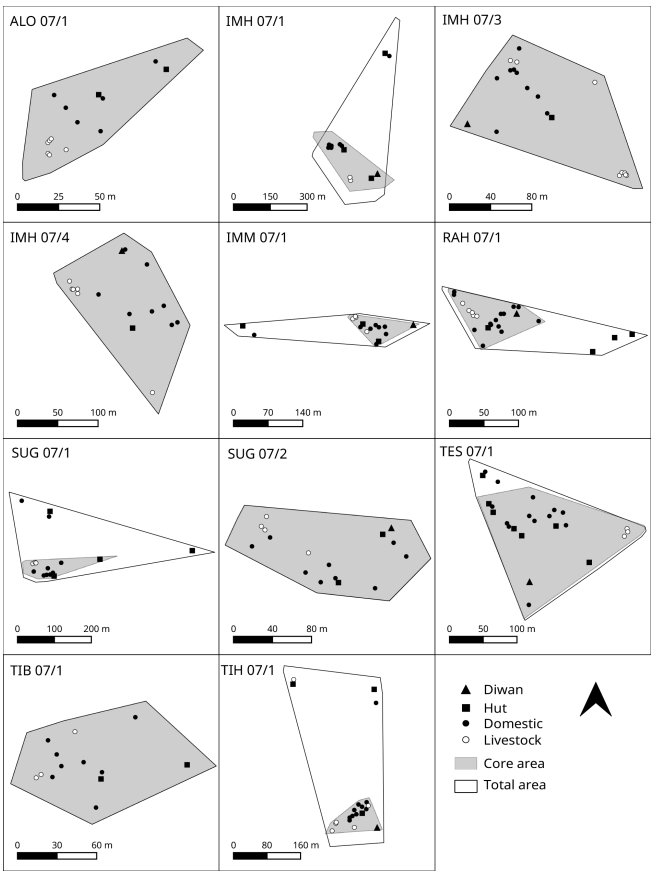
The Ripley-Rasson estimate provides a quantitative assessment of the areal extent of each campsite by computing a "convex hull" of the features (i.e., the smallest convex polygon including all observed points), which is then rescaled on the basis of the number of observations and vertices. Although this remains just an etic definition of the settlement area, it offers a reproducible and a first quantitative account for evaluating our data set, as well as an attempt to estimate the combination of the residential space (i.e., the physical space occupied by the structures) and the occupational space (i.e., the empty space that is daily crossed; sensu Fletcher 1981).

The results of our analysis (see Table 3) showed that settlements have an average size of 3.6 ha, although the distribution has a strong right skew, with the largest settlement more than 13 ha. This skew is most likely caused by the fact that the estimate also incorporates the void between the core area and the space occupied by the unmarried sons, which is emically regarded as part of the settlement. As noted earlier, this isolation is regarded as a voluntary choice to maintain spatial and age-based segregation, although it does not prevent daily interaction and communication (Fletcher 1981). Given the particular role played by the unmarried sons in the shaping of the settlement layout, and their potential conflating effect in the study of the isolation of *diwans*, we decided to focus our analysis on the core rather than the extended areas of the settlements (see Fig. 3). Our choice of excluding all features belonging to the unmarried offspring was also dictated by our explicit interest in the original blueprint of the Kel Tadrart campsites, and not the subsequent changes in the spatial layout resulting from settlement expansion. The resulting average size was reduced to 1.34 ha, although this was greatly driven by the reduction in size of the IMH 07/1 (from 13.80 to 3.66 ha) and TIH 07/1 (from 7.51 to 0.66 ha) sites.

Table 3. Estimates of Kel Tadrart settlement areas computed with the Ripley-Rasson analysis using all features for extended area, and excluding structures pertaining to unmarried sons for core area.

Settlement	Area total (ha) → extended area (ha)	Area core (ha)
ALO_07/1	0.42	0.42
IMH_07/1	13.80	3.66
IMH_07/3	1.46	1.46
IMH_07/4	1.91	1.91
IMM_07/1	1.71	0.44
RAH_07/1	1.49	0.61
SUG_07/1	6.63	0.81
SUG_07/2	1.39	1.39
TES_07/1	2.93	2.51
TIB_07/1	0.87	0.87
TIH_07/1	7.51	0.66

Fig. 3. Different features and areas at Kel Tadrart campsites.



The isolation of livestock features

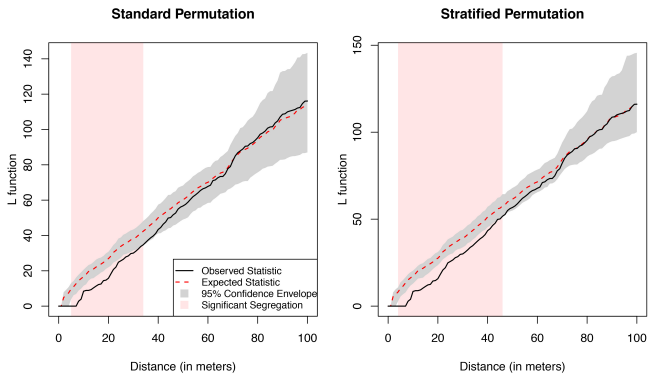
Because Kel Tadrart campsites do not feature any physical boundary separating domestic and livestock spaces, we chose to formulate our hypothesis in terms of spatial relationship between feature types. More specifically, we conducted a bivariate *L* function (Diggle 2003; see also Crema and Bianchi 2013 and Bevan et al. 2013 for archaeological examples of its application), a point process analysis designed to evaluate whether two sets of points exhibit aggregation or segregation at different spatial scales (see also Smith 2004). We first defined a binary membership of all features to either the domestic domain (class D, n = 121) or the livestock domain (class L, n = 49). Then for each point of class D, we calculated the number of points of class L located within distance *r*. This formed the basis of our summary statistic, which was then adjusted with the total number of observed points and the size of the window of analysis (obtained with the Ripley-Rasson estimate; see publications above for technical details about the bivariate *L* function). For each distance *r*, this observed statistic was then compared with an envelope generated from 10,000 simulated statistics, each calculated from a random permutation of the points' labels, i.e., membership in the domains. The comparison between the observed and simulated statistics enabled us to determine whether we had significant instances of attraction (the observed *L* function was higher than the simulated

envelope, i.e., the number of points of class L from each point of class D was higher than expected) or repulsion (the observed *L* function was lower than the simulated envelope).

As mentioned earlier, the small number of observations for each campsite did not allow an analysis at the level of individual sites. Instead, we carried out our analysis by aggregating the entire data set under the assumption that the same spatial process took place in all sites. Although this approach inevitably hindered any exceptions or deviations from the general pattern, it provided a formal way to assess the general spatial relationship between domestic and livestock features. We generated our simulated summary statistics in two ways: (1) by freely permuting the entire data set, thus without keeping the relative number of class L and class D points for each site (i.e., each simulation had in total the same number of class L amd D points as the observed data, but their number at each site could be different from the number observed); and (2) by stratifying the permutation so that the relative proportions of class L amd D points were also maintained at the site level.

The results (Fig. 4) showed that for both cases the observed *L* function was lower than the simulated envelope, indicating a significant segregation between class D and class L features. The choice of the permutation procedure did not alter the output in a significant fashion, with the scale of segregation (highlighted in red in Fig. 4) between 5 to 35 m for the standard permutation approach and 5 to 45 m for the stratified version. In other words, on average the expected density of livestock features within a distance of 5 to approximately 40 meters from every domestic structure was significantly lower than one would expect from a purely random relationship in the use of space.

Fig. 4. Result of the bivariate *L* function for the full permutation and constrained permutation versions of the null hypothesis. The pink shaded region highlights spatial scales of significant segregation between domestic and livestock features (analysis run on 10,000 Monte Carlo simulations).



The isolation of the *diwans*

To test our hypothesis that *diwan* huts were isolated from other residential features in the same campsite, we developed a bespoke, permutation-based statistical analysis. For each campsite (n = 8, because 3 campsites did not have a *diwan*), we first calculated a matrix of interdistances between all domestic features and *z*-transformed the values to ensure comparability across differently sized settlements. We then computed the average *z*-transformed distances from the *diwan* to all domestic features for each campsite and calculated the grand mean of our observed data, i.e., the mean of the means. This summary statistic, which we will refer to as I_{observed}, offers an index of the degree of isolation of *diwan* huts from all other domestic features. Our null hypothesis was that *diwans* do not have any particular spatial position; hence, their distance from the domestic space would be comparable to those of other huts. If that is the case, I_{observed} would be indistinguishable from the same statistic computed from a selection of random huts as *diwans* (one per campsite, as for the observed data). Given the small sample size, we calculated the summary statistic for all 1728 possible combinations (including the observed) where 1 hut in the campsite was randomly assigned as a *diwan*. The number of huts (excluding unmarried offspring and including *diwans*) was 3 (IMH_07/1), 2 (IMH_07/3), 2 (IMH_07/4), 3 (IMM_07/1), 2 (RAH_07/1), 3 (SUG_07/2), 4 (TES_07/1), and 2 (TIH_07/1). The product of all terms ($3 \times 2 \times 2 \times 3 \times 2 \times 3 \times 4 \times 2 = 1728$) gives the total number of possible combinations where one hut per campsite was a *diwan*. The results showed that the observed statistic was the highest possible, implying that the probability of getting a value as large as (or greater than) I_{observed} by chance alone is 1 out of 1728, or 0.0005787037, which is the exact *p* value of our test. Our analysis thus strongly supports the hypothesis that indeed *diwans* are the most isolated huts among the residential features because this was systematically the case for all eight settlements examined here. In other words, the seclusion has a material correlate that is reflected in the spatial layout of Kel Tadrart campsites.

DISCUSSION AND CONCLUSIONS

Despite the prominence of pastoral communities in the past and present landscape of the Sahara, there are very few studies offering a quantitative account of their campsites and virtually no statistical assessments on visual and qualitative impressions of their spatial layout. Our study is an initial attempt to fill the gap in the knowledge by applying a suite of techniques developed in the field of point pattern analysis.

The Ripley-Rasson estimate has offered an objective, repeatable, and reproducible quantification of the site area, information that is often lacking in the study of pastoral communities. We obtained estimates of the original settlement area, as well as the extended area after the construction of features associated with unmarried sons (Table 3). We then tested two hypotheses that were proposed in past studies but never verified in statistical fashion: the segregation of domestic and livestock spaces and the isolation of *diwan* huts. Our analysis suggests that the empirical evidence offered by the Ket Tadrart campsites supports both hypotheses despite the small number of features observed at each settlement.

On average, our analysis suggested a segregation of livestock and domestic features at the scale of 5 to approximately 40 meters (Fig. 4). The result could testify to functional needs, but could also be reconnected to the neat Kel Tadrart vision of clean (huts) and dirt (the livestock dung and related areas). This contrasts with other African cattle-based pastoral societies, where the corral is set at the very center of the settlement (e.g., Hodder 1982). The lack of comparative spatial data from other pastoral societies prevents further speculation regarding the presence of this segregation and the scale at which this occurs among herders from

the Levant and the Near East, although some of the figures presented (e.g., Fig. 4 in Simms 1988 and Fig. 4 and Fig. 5 in Banning and Köhler-Rollefson 1992) do not seem to indicate a clear separation in space, suggesting the necessity of further analysis. Given that in many cases it is possible to distinguish domestic and livestock features, we reckon that this analysis can be applied also to the archaeological record, although chronometric uncertainty might hinder a proper evaluation of the spatial relationships (but see Crema et al. 2010 for a possible solution). This is not the case for the isolation of *diwans*, because the material evidence of these special-purpose huts is virtually indistinguishable from that of other residential units (Biagetti 2014*c*). Our research can be considered a cautionary tale on how specific social attitudes might be expressed only within a relational space, prompting the necessity of more formal analysis of settlement layouts.

It is also worth noting that alternative social processes other than the ones proposed here can also generate both observed spatial patterns. Such an equifinality problem is likely to be even more limiting in the case of archaeological data, although some possible solution has been suggested (see Eve and Crema 2014). In general we believe that the application of spatial statistics can actively contribute to the study of pastoral societies. The existence of functional and social stresses that need to be spatially managed at the campsite level certainly affects many communities other than the Kel Tadrart. The relevance of the set of rules we have identified here ought to be framed within a larger cross-cultural framework. The use of objective, repeatable, and reproducible statistical analysis is pivotal to this endeavor. It is also worth noting that the methods presented here are just a small portion of a wider range of techniques that are able to discern patterns resulting from the interaction of individual components (inherent spatial dependency) from those emerging from external constraints such as local topography (induced spatial dependency). These methods have been primarily used either for the analysis of artifact distribution (e.g., Orton 2004, Vanzetti et al. 2010, Crema and Bianchi 2013; see also Carrer 2015 for ethnoarchaeological application) or for the study of regional settlement pattern (e.g., Bevan and Connolly 2006, Winter-Livneh et al. 2010, Palmisano 2013), and rarely for the intermediate scale assessed here (but see Eve and Crema 2014). Rather, the originality of our approach resides in the application of such methods to a whole set of ethnographic data, collected with ethnoarchaeological purposes.

Although this case study bears relevance to the broad domain of human spatial behavior, it holds insights for archaeological research on nomadism as well. The paucity of extensive excavations limits the comparative study of multiple campsites in the archaeology of the Tadrart Acacus and in general of the central Sahara. We focused on regional surveys (e.g., Cremaschi and di Lernia 1998, Biagetti et al. 2013) coupled with small-scale excavations (see Biagetti and di Lernia 2013 for a recent review). How ephemeral or elusive these can be, the material traces left on the ground by ancient pastoralists, can be better pinned down by an ethnoarchaeological perspective aimed at collecting spatial data to reconstruct settlement layouts. We believe that the combination of ethnoarchaeologically sourced data and the flexibility of modern spatial statistics can offer an excellent contribution to the field of settlement studies in small-scale societies.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8202

Acknowledgments:

Data used in this study were collected by one of the authors (SB) under the logistical and financial support of the Italian Archaeological Mission in the Sahara.

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