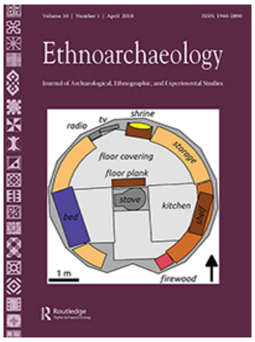


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# Occupancy and the Use of Household Space Among the Dukha

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# Occupancy and the Use of Household Space Among the Dukha

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**ABSTRACT**
Archaeologists commonly encounter the occupation surfaces of ephemeral prehistoric houses. Within those spaces, artifacts can exhibit considerable spatial structure raising the question of what that structure can tell us about human behavior. We explore a simple site-formation model in which household *occupancy*, defined here as the average number of individuals who simultaneously occupy a house, positively predicts artifact dispersion. We confront the model with ethnographic observations on the use of space in 19 houses inhabited by Dukha reindeer herders of the Mongolian Taiga. The analysis shows that average occupancy predicts dispersion in the use of household space but that systemic noise, sampling error, and event mixing are likely to overwhelm the behavioral signal. Other factors may therefore be equally or more important in driving the spatial dispersion of household artifacts. The study further suggests an analytical framework for exploring relationships between behavior and archaeological structure using ethnoarchaeological data.

**KEYWORDS**
Occupancy; mobile societies; spatial analysis; Dukha; Mongolia; houses; lithics; Taiga

Archaeologists have excavated thousands of artifact clusters representing past domestic surfaces, often hearth-centered activity areas (e.g. Alperson-Afil et al. 2009; Audouze and Enloe 1997; Bodu, Karlin, and Ploux 1990; Carr 1991; Clark 2017; Koetje 1983, 1987, 1994; André Leroi-Gourhan and Brézillon 1966, 1983; Simek 1984a; Stevenson 1985; Stiger 2006). Artifacts associated with such domestic surfaces often exhibit considerable spatial structure raising questions about the extent to which such patterns reflect systemic behaviors or post-depositional processes (sensu Schiffer et al. 2010). Although considerable attention has been paid to site-level spatial analysis (Kroll and Price 1991; O'Connell, Hawkes, and Blurton-Jones 1992; O'Connell 1995; Yellen 1977), less effort has been devoted to understanding structure at a household scale.

We are particularly concerned here with the houses of mobile societies. The small and ephemeral nature of such houses pose considerable challenges for archaeological detection and interpretation. Drawing largely on ethnoarchaeological observations, Binford (1983) proposed that distinct "drop and toss" zones could be recognized archaeologically and

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interpreted as hearth-centered activities. Stapert and colleagues (Stapert 1989; Johansen and Stapert 2003; Stapert and Street 1997) and Surovell and Waguespack (2007) presented more rigorous methods for detecting and describing such spatial patterns and further argued that spatial patterns in artifact distributions could be used to detect the presence or absence of house walls. These and other analyses furthermore highlighted the need for additional research on the behavioral drivers of spatial structure in household level artifact distributions (Audouze and Enloe 1997, 206; Stapert 1989, 54; Surovell and Waguespack 2007, 251; Surovell et al. 2005; Simek 1984b, 418). Perhaps most notably, distinct asymmetries in the distributions of artifacts around central hearths have generated behavioral models related to wind protection, functional differentiation of space, and gendered use of space.

Fortunately, some residentially mobile populations still occupy small ovoid dwellings similar to those likely used by mobile societies of the past. Systematic observation of the use of space in such dwellings can offers insights into how various behaviors structure the use of space, the extent to which material distributions reflect such structured use of space, and the extent to which such distributions persist through subsequent activities. In the analysis presented here, we draw on ethnoarchaeological observations of household use of space among the *Dukha*—a small population of approximately 280 residentially mobile reindeer herders who inhabit the Mongolian Taiga of the Khövsgöl Province near 99° east longitude, 51° north latitude, 2,000 m above sea level (Inamura 2005; Surovell and O'Brien 2016; Walker 2009; Wheeler 2000). The Dukha are one of few modern human populations to reside in small ovoid dwellings that are moved periodically throughout the year (Figure 1). Spring through summer houses tend to be tipi forms locally known as *ortzen ger*. Winter houses include *ortzen ger*, the traditional *ger*, and small log cabins. *Ger* and *ortzen ger* have a central stove. Floor coverings are often present. Furniture including beds, electronics, kitchen items, and shelving are distributed near the outer margins of the interior space. A toroid-shaped space centered on the hearth is generally kept free of materials and provides space for movement and various activities.

Dukha households offer an opportunity to evaluate household use of space and its drivers among residentially mobile populations. In this analysis, we are particularly interested in how *occupancy*—the number of individuals occupying a house—affects dispersion in the use of household space and, in turn, how the accumulation of many household occupation events affects that relationship. In other words, we wish to know the extent to which the systemic property of household occupancy generates observable structure in the use of space and, in turn, the extent to which that structure persists with repeated use of space. Such observations can ultimately contribute to a behavioral understanding of spatial structure in the archaeological record.

Our analysis begins with a model for the relationship between occupancy and the dispersion of household artifacts. Following from basic geometric constraints and qualitative observations on the household use of space among the Dukha, we posit that household occupancy positively predicts dispersion in the use of household space, which in turn positively predicts dispersion in discarded materials. That is, we expect higher household occupancy to generate higher degrees of dispersion in the use of household space and associated materials. The archaeological implication of the proposed relationship is that artifact dispersion in archaeological houses could be used to infer relative household occupancy.

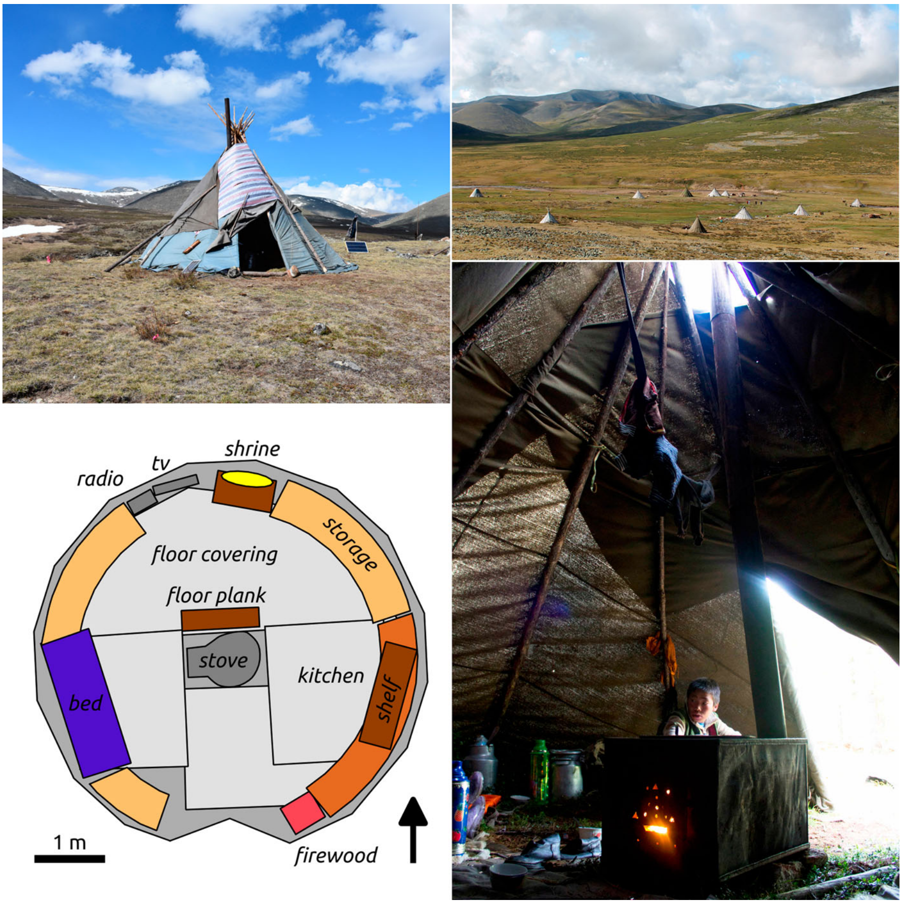


**Figure 1.** Dukha household space. Top Left: Exterior of a typical ortzen gar. Top Right: A Summer camp in the west taiga. Bottom Right: A young Dukha individual sits by the stove in a Fall ortzenger. Bottom Left: Layout of a typical Dukha house including a central stove, floor coverings, and furniture placed around the perimeter. Doorways are typically oriented to the south. Photographs by Todd Surovell.

## Modeling the effect of occupancy on artifact dispersion in mobile households

Modeling the relationship between occupancy and artifact dispersion begins with the systemic context in which behavior occurs and artifacts are deposited (sensu Schiffer 1972). We can readily imagine a number of exogenous and endogenous factors driving the systemic use of household space. Certain activities, cultural idiosyncrasy, furniture, gender ideology, house form, household size, individual idiosyncrasy, light availability, seasonality, and warmth are just a few of the many factors that can be readily imagined to affect household use of space. Moreover, such factors and their combinations conceivably affect various dimensions of the use of space. For example, we might expect cold-season temperatures to increase the overall intensity of house use (one dimension of variation) as well as bias the use of space closer to central hearths and away from drafty walls (another dimension of variation). Ultimately, unpacking which behaviors predict which dimensions of variation requires theory driven analysis.

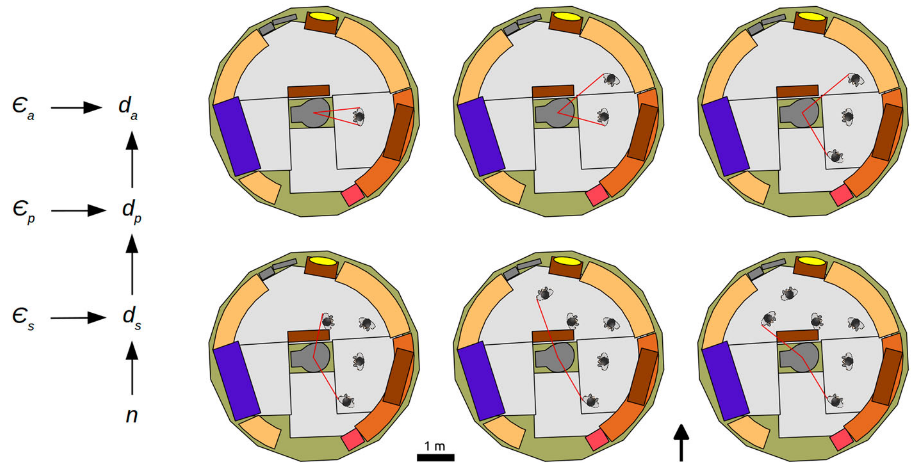


**Figure 2.** Graphical depictions of the working model for the relationship between household occupancy, n, and material dispersion, $d_a$, in mobile households. As the number of occupants increase from 1 to 6 individuals, angular dispersion increases (indicated by red lines). Occupancy with systemic error, $\epsilon_s$, affects spatial dispersion, $d_s$. The spatial dispersion of production activities, $d_p$, is a subset of $d_s$, thus introducing sampling error, $\epsilon_p$. The spatial dispersion of production activities gives rise to spatial dispersion in artifacts, $d_a$, which is also affected by sampling error and error introduced by subsequent disturbance processes, $\epsilon_a$. In sum, larger households are expected to generate greater angular dispersion in the use of space and associated materials.

Basic geometry in combination with qualitative field observations have lead us to hypothesize that a major driver of spatial structure in Dukha households is spatial crowding, or *occupancy*—the number of individuals simultaneously occupying a house. Our intuition for how occupancy affects spatial dispersion is that the first individual in a given house tends to occupy a "sweet spot," *s*, typically in the kitchen area, which is always located east-northeast of the central stove (Figure 2). We have observed that the matriarch of the house often occupies such a location. Subsequent individuals who enter the house tend to fill space around earlier occupants in arcing fashion around the central stove. We note that an ethnoarchaeological study of modern U.S. households similarly found kitchens to be a center of household activity (Arnold 2012). The authors suggest that modern U.S. kitchens are incarnations of hearths, which similarly served as concentrations of activity among human households extending back to Paleolithic times.

Given such a space-filling model, the number of individuals, *n*, simultaneously occupying a house should positively covary with the horizontal dispersion of occupied space, $d_s$, relative to *s*. That is, $d_s \propto n$(Equation 1). This basic relationship may not be entirely straightforward, however, because people of course move through houses as they perform various activities, and the spatial dispersion of a single moving individual could approximate the spatial dispersion of multiple stationary individuals. We should also expect observation error in spatial positioning to further complicate the basic model. Last, the mixing of multiple occupancy events can complicate the relationship given that archaeological houses are not static snapshots of household use, but rather palimpsests of many uses (Binford 1981; Schiffer 1985). For the purpose of this analysis, the sum of all extraneous behaviors, observation errors, and systemic mixing are collapsed into an error term, $\epsilon_s$, which in combination with Equation 1, gives the relationship $d_s + \in_s \propto n$ (Equation 2).

Another important consideration in modeling the use of space and its archaeological correlates is the differential deposition of archaeologically detectable materials. Due in large part to the historical replacement of stone tools with metal implements, the campsites of ethnographically documented modern peoples are extremely impoverished in things that would be considered "artifacts" in archaeological contexts. For example, in his classic study of !Kung campsites Yellen (1977, 88) noted, "Iron knives, axes, and adzes, which form the core of the !Kung tool kit are never left behind, and only once in the course of my work did I discover a lost tool." In !Kung campsites, Yellen typically recorded 100-300 faunal skeletal elements, a few tin cans, and a small scatter of floral remains in campsites ranging in area from 60 to over 500 $m^2$. With such low densities (~1 item per $m^2$), it should come as no surprise that Yellen's study focused on spatial patterns on the scale of entire campsites—a scale at which archaeologists rarely operate. Similarly, O'Connell identified a number of spatial patterns in an Alyawara camp, but concluded that "patterns in site structure will be identified only in relatively large scale exposures, at or beyond the largest now undertaken in hunter-gatherer sites" (O'Connell 1987, 104). Yet, we know from the archaeological record that there is considerable spatial structure among artifacts, especially ubiquitous lithic artifacts, within archaeological sites. There has therefore been a clear scalar disconnect between spatial ethnoarchaeology and the spatial archaeology it is intended to serve.

This is in part why we have shifted the focus from the mapping of material remains to the direct mapping of people. It allows us to examine spatial patterning at scales commensurate with archaeological excavation. This method does raise the question of how human spatial positioning relates to the material record that it would produce if people were still using stone tools. It is important to note that an alternative approach might be to seek some modern material analog of chipped stone, but we contend that there is none. Furthermore, like !Kung and Alyawara campsites, very little in the way of a material record is left behind in Dukha camps. Nonetheless, we think it is fair to assume that the spatial positioning of humans engaged in production activities can serve as a general proxy for lithic-use activities. In other words, production activities in mobile households today likely approximate the lithic-use activities in mobile households of the past.

A number of household production tasks, especially cutting, drilling, scraping, graving, and sawing tasks, would have required lithic tools in the past. Loss, breakage, resharpening, and discard of lithic tools can therefore result in the deposition of lithic materials. While such production activities may have tended to occur in different household spaces than other activities, the dispersion of production activities, $d_p$, should nonetheless respond positively to occupancy in the same way that any other activity would. That is, higher occupancy should result in greater dispersion in production activities. Thus, we can consider production activities a statistical subset of all household activities, $d_p \subset d_s$ (Equation 3). Substituting $d_p$ for $d_s$ in Equation 2 and introducing sampling error that results from taking a subset of the population gives the equation, $d_p + \in_s + \in_p \propto n$ (Equation 4).

Production activities are expected to result in the deposition of archaeological materials. To the extent that those materials are deposited at the locations of production, material dispersion, $d_a$, can be expected to index the dispersion of people engaged in production activities, $d_p$. That is, $d_a \subset d_p$ (Equation 5). Of course, additional error is introduced with the use of materials as spatial indicators. The deposition of materials reflects a subset of moments in which production activities take place, thus introducing additional sampling error. Moreover, the spatial positions of deposited materials are likely to be altered due to unintentional displacement from kicking, intentional displacement due to cleaning, or post-abandoment displacement by natural processes such as rodent burrowing or tree falls. We represent the sum of such post-depositional artifact displacements with the error term, $\epsilon_a$. Substituting $d_a$ for $d_p$ and adding the error term for the displacement of artifacts gives the expression $d_a + \in_s + \in_p + \in_a \propto n$ (Equation 6).

In the case of lithics deposited by mobile societies who ephemerally occupy locations, such post-depositional alteration may be minimal. In his ethnographic review of lithic depositional patterns, J.E. Clark (1991, 78) concluded that, " … different types of societies, as roughly assessed by patterns of residential mobility and subsistence practices, treat knapping refuse differently. Some groups … practice preventative maintenance; others … allow knapping debris to remain in its primary place as defacto refuse" (see also J. E. Clark 1986). Clark furthermore showed that even when cleaning of lithic debris was emphasized, small pieces were preferentially left in place and became incorporated into the living surfaces. More to the point, our ethnoarchaeological observations do not permit evaluation of such post-depositional alterations to production-material distributions given that the Dukha do not use stone tools. Nonetheless, the absence of that source of error does not undermine the utility of this analytical exercise. The ethnographic data permit evaluation of the first two links in the model chain, $d_s$ (dispersion of occupied space) and $d_p$(dispersion of people). It is critical to evaluate those relationships and the effects of error prior to evaluating $d_a$(artifact dispersion) given that early-stage systemic error could obviate the effects of late-stage error.

In sum, the working model suggests that the household occupancy, $n$, is proportionate to the dispersion of archaeological materials within a house. That is, more occupants are expected to generate greater dispersion in archaeological materials. System error is expected to complicate the model, but the extent to which it does is unclear and is the subject of the current ethnoarchaeological investigation. The model generally predicts the following structural properties in the data: (1) central tendency in the use of household space, (2) increasing dispersion in human use of space as a function of increasing occupancy, (3) increasing spatial dispersion in production activities as a function of increasing occupancy, (4) increasing spatial dispersion in all activities as a function of increasing average occupancy at the house level, and (5) increasing spatial dispersion in production activities as a function of increasing average occupancy at the house level. Each prediction is associated with noise, beginning with noise related to individual human spatial positioning in 1-3 and noise related to mixing of many events in 4 and 5. The point at which the predictions fail should tell us the point at which system error has overwhelmed the occupancy signal or that model assumptions are faulty.

## Materials and methods

Our case study includes 4129 observations on the use of space among 19 Dukha houses at six camps between July 2012 and June 2016 (Figure 3; Table 1). The camps that we observed had between 2 and 10 houses, each with simultaneous occupancy ranging from 1 to 11 individuals. Our observations included the documentation of spatial locations and activities of individuals within the structures. In general, observation sessions were conducted over 20-minute intervals with the observer sitting at some location in the house plotting the approximate spatial positions and activities of individuals. Observers would try to sit at different locations in each observation session in order to minimize their influence on the overall structure of observations. One observation was made every minute in the observation set, alternating each minute among occupants if more than one was present. This method of serial recording of individuals systematized the process and prevented difficulties in keeping pace during particularly crowded or active times.

Spatial dispersion is operationalized as the angular dispersion of a set of spatial observations relative to the angular mean. Angular measurements are made on a polar grid with the origin at the center of the house and oriented such that the doorway is fixed at 180° (see Figure 1). Dukha houses tend to be oriented south-southeast, so this doorway-oriented grid approximates geographic orientation. All angular calculations were performed using R statistical computing language and the R package, "circular" (R Core Team 2013; Agostinelli and Lund 2013).

Occupancy is operationalized by counting the number of individuals present in an observation session. Though this method is imperfect, it serves as a necessary index of occupancy given the difficulties of consistently capturing moments in time in these dynamic systems. Mean occupancy is calculated as the sum of occupancy measures per observation session divided by the number of observation sessions.

We also explored a more complicated index of occupancy to account for fundamental limitations of our recording method. This method incorporated both the number of

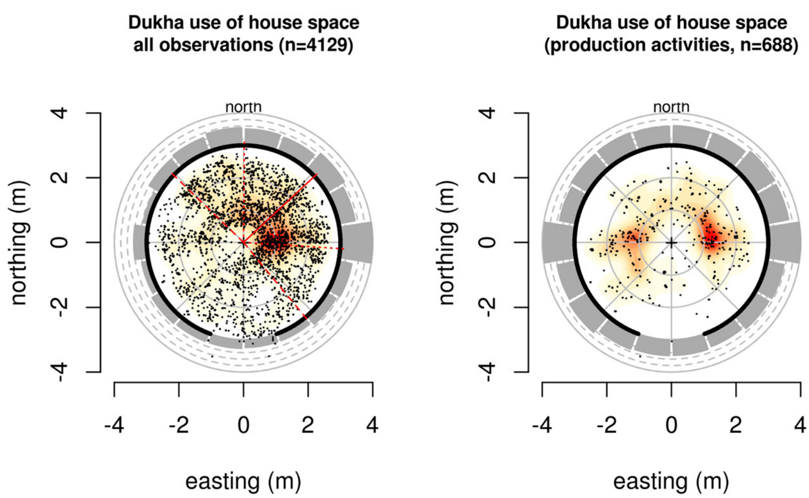


**Figure 3.** Observations (black dots) on 4306 spatial locations of individuals in 19 Dukha houses collapsed into a single plot (left) and on 685 spatial locations of individuals engaged in production activities (right). The underlying color grid specifies 1 m kernal density of observations with red indicating highest density and white indicating lowest. The circular histogram around the perimeter of the map indicates a tendency to use the northeast half of the house. The solid red line indicates the mean orientation, fine-dashed lines indicate 1 standard deviation, and coarse dashed lines indicate two standard deviations. The black arc indicates the house wall with doorway to the south.

**Table 1.** Summary of spatial observation data in Dukha houses.

| Site | House | Season of observation | House type | Observation sessions | Unique occupants | Total observation time (mins) | Mean occupancy | All observations | Production observations |
|---|---|---|---|---|---|---|---|---|---|
| A | 1 | Summer 2012 | ortzen ger | 18 | 22 | 198 | 5 | 201 | 34 |
| A | 3 | Summer 2012 | ortzen ger | 19 | 16 | 147 | 3.2 | 154 | 5 |
| A | 4 | Summer 2012 | ortzen ger | 12 | 5 | 74 | 2.4 | 78 | 11 |
| A | 5 | Summer 2012 | ortzen ger | 16 | 16 | 72 | 2.7 | 88 | 10 |
| A | 6 | Summer 2012 | ortzen ger | 9 | 23 | 153 | 5.9 | 163 | 24 |
| A | 7 | Fall 2014 | ortzen ger | 14 | 10 | 104 | 2.4 | 118 | 14 |
| B | 1 | Fall 2014 | ortzen ger | 49 | 9 | 607 | 2.5 | 627 | 139 |
| B | 2 | Fall 2014 | ortzen ger | 25 | 9 | 333 | 2.4 | 271 | 43 |
| C | 1 | Winter 2015/16 | ger | 24 | 10 | 367 | 3.3 | 321 | 41 |
| C | 2 | Winter 2015/16 | ger | 16 | 14 | 259 | 4.1 | 227 | 6 |
| C | 3 | Winter 2015/16 | ger | 4 | 6 | 66 | 3.8 | 67 | 3 |
| D | 1 | Spring 2016 | ortzen ger | 68 | 9 | 1151 | 3.2 | 1141 | 277 |
| D | 2 | Spring 2016 | ortzen ger | 5 | 6 | 57 | 2.2 | 51 | 0 |
| D | 3 | Spring 2016 | ortzen ger | 9 | 8 | 133 | 2.8 | 97 | 14 |
| E | 1 | Spring 2016 | ortzen ger | 8 | 9 | 107 | 3 | 115 | 11 |
| E | 2 | Spring 2016 | ortzen ger | 5 | 6 | 78 | 2.8 | 69 | 12 |
| E | 3 | Spring 2016 | ortzen ger | 5 | 5 | 31 | 2.6 | 35 | 0 |
| F | 1 | Spring 2016 | ortzen ger | 15 | 7 | 235 | 3.7 | 232 | 29 |
| F | 2 | Spring 2016 | ortzen ger | 6 | 5 | 69 | 2.8 | 74 | 15 |

unique individuals in an observation set and the number of times temporally adjacent pairs of observations shifted between different individuals. The rationale for incorporating these observational "shifts" into the occupancy calculation is that our recoding method could at times fail to distinguish between more and less crowded rooms. For example, an observation set including three individuals sequentially recorded as 1,2,3,1,2,3,1,2,3 (8 shifts) likely indicates that all three individuals occupied the house simultaneously. In contrast, an observation set including the same number of individuals recoded as 1,1,1,2,2,2,3,3,3 (2 shifts) likely indicates that there were only ever two individuals in the house at the same time and never all three individuals at the one time. Thus, all other things being equal, more crowded rooms ought to result in higher frequencies of shifts than less crowded rooms, and incorporating observational shifts into an occupancy index should mitigate that source of potential error. However, we found that using observational shifts in the calculation of occupancy did not significantly affect the results. We therefore feel confident that the number of individuals per observation session is a reasonable proxy for occupancy and opted to use the simpler occupancy index for ease of interpretation.

*Production activities* are generally considered activities that entail the alteration of materials that could conceivably result in material deposition. Because we are mainly concerned with the deposition of durable materials, production activities refer to a more-specific set of tasks. We coded production activities as any activity that involved cutting, drilling, sawing, scraping, or slicing. While the Dukha tend to perform such tasks with metal tools, past societies would likely have performed them with flaked stone tools, which would have resulted in occasional discard of the tools, fragments of the tools, or resharpening debitage.

## Results

First, our analysis of 4129 observations on the household spatial positions of Dukha individuals shows clear central tendency in how individuals use space. The circular mean of all observations is oriented at $47.1 \pm 93.2°$ (mean ± sd; see Figure 3). A Watson's test of circular uniformity indicates that the central tendency departs significantly from a uniform distribution (Test statistic: 15.7, $p < 0.01$) thus supporting the hypothesis of a sweet spot in the use of space in Dukha houses.

Second, our analysis of numbers of individuals and their spatial dispersions in discrete observation sets shows that the number of individuals occupying a Dukha house significantly predicts increased dispersion in the use of household space (Figure 4). For every individual added to a Dukha house, angular dispersion in the use of space tends to increase by $8.5 \pm 0.9°$ ($F = 88.6$ on 1 and 325 d.f., $p < 0.01$). However, error in the relationship is considerable with 79 percent of the spatial dispersion unexplained by occupancy. Nonetheless, we find that the signal of occupancy is sufficiently strong to show through systemic noise.

Third, our analysis indicates that occupancy significantly predicts increased dispersion in production activities. Figure 3 shows the spatial distribution of all production activities, and Figure 5 plots the relationship between spatial dispersion in production activities as a function of occupancy for each observation set. For each individual added to a Dukha house, angular dispersion in the use of space tends to increase by $3.7 \pm 1.4°$ ($F = 6.9$ on 1 and 140 d.f., $p = 0.01$). While the relationship is significant, its predictive power is

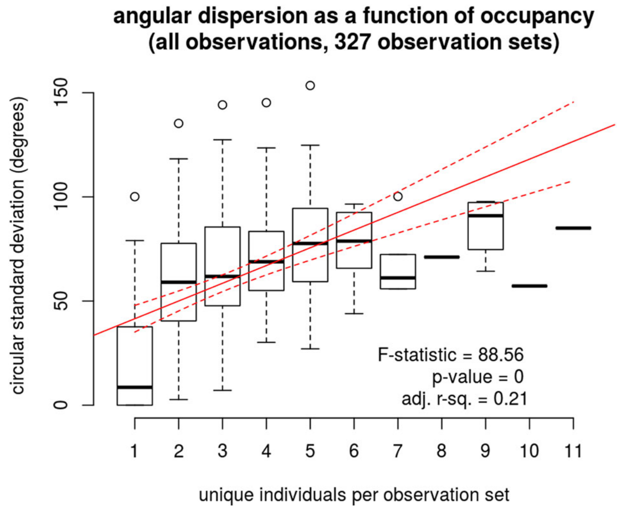


**Figure 4.** Relationship between spatial dispersion and occupancy in Dukha houses. Each box-and-whisker plot represents all observation sets for a given occupancy count. Observation sets includes approximately 20 spatial positions recorded over approximately 20 min. Spatial dispersion is measured as the circular standard deviation (degrees) of the positions relative to the center point of the house with doorway oriented at 180°. The trend line with 95% confidence intervals indicate a significant positive relationship ($F = 88.56$, $p < 0.01$), albeit with considerable noise (adj. $r^2 = 0.21$).

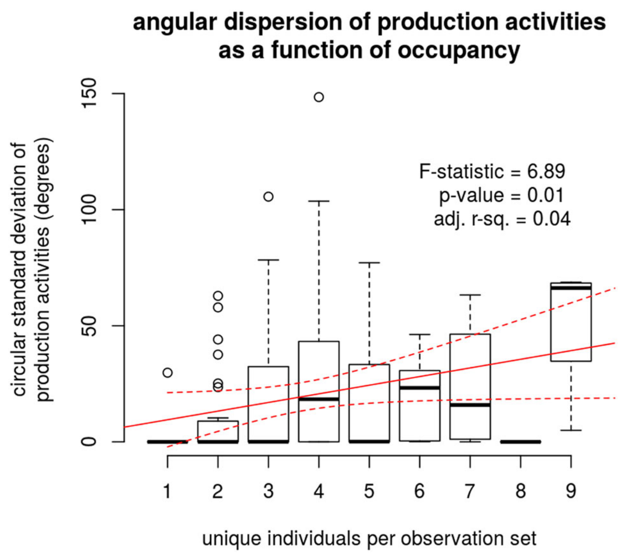


**Figure 5.** The dispersion of production activities as a function of occupancy. Occupancy predicts a significant increase in dispersion of production activities, but the relationship is weak.

extremely low. Occupancy accounts for a mere 4 percent of the variation in the angular dispersion of production activities. We therefore find that the signal of occupancy is still evident in the dispersion of production activities but that sampling production activities significantly diminishes the signal to noise ratio.

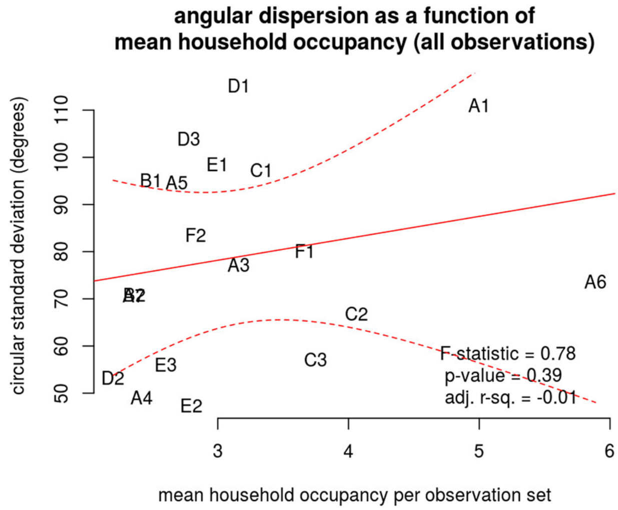


**Figure 6.** Positional dispersion of all activity locations measured in circular standard deviation as a function of mean household occupancy. Symbols reflect site/house designations.

Fourth, we observe that when observations are aggregated by house, average spatial dispersion responds positively to occupancy with an increase of 4.7 ± 5.2° for each unit of increase in average house occupancy; however, this trend is statistically indistinguishable from zero association ($F = 0.78$ on 1 and 17 d.f., $p = 0.39$). It is therefore apparent that mixing of events overwhelms any signal of occupancy (Figure 6).

Finally, we observe that when production activities are aggregated by house, average spatial dispersion responds to average occupancy with an change of -0.11 ± 0.2° for each unit of increase in average house occupancy (Figure 7); however, this trend is statistically indistinguishable from zero association ($F = 0.44$ on 1 and 15 d.f., $p = 0.51$). It is

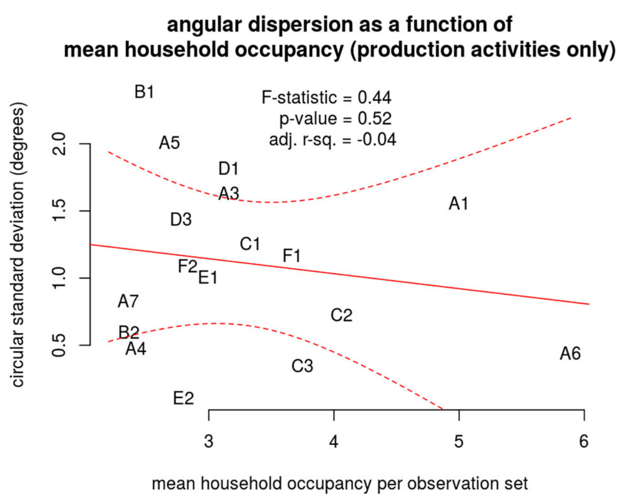


**Figure 7.** Positional dispersion of production activity locations measured in circular standard deviation as a function of mean household occupancy. Symbols reflect site/house designations.

therefore apparent that mixing of multiple production events overwhelms any signal of occupancy in Dukha houses.

## Conclusions and discussion

We began this analysis by advancing a simple model for the relationship between house occupancy and spatial dispersion in the distribution of household production activities—activities that are likely to have produced lithic debris in the past. Following from basic household geometry and qualitative observations of Dukha household use of space, we proposed that household use of space exhibits central tendency and that spatial dispersion around that tendency should positively respond to increasing occupancy. At face value, such a relationship would hold implications for reconstructing relative household occupancies from spatial dispersions in prehistoric household records. However, we further considered that systemic and post-depositional noise could conceivably obscure the relationship.

Our analysis of Dukha households shows that there is central tendency in the use of space and that increasing occupancy significantly increases dispersion around the central tendency. For each additional individual added to a house, angular dispersion around the central hearth tends to increase by approximately 9°. However, systemic processes introduce considerable noise into the relationship with 79 percent of the variation left unexplained. Moreover, with each additional level of noise added, the predictive power of occupancy on spatial dispersion rapidly diminishes. When considering only the subset of production activities—activities that are most likely to introduce materials into archaeological records—the relationship remains significantly positive albeit with low predictive power. When we consider the effects of mixing multiple occupancy events, the relationship becomes completely obscured. While there is good reason to expect an association between occupancy and spatial dispersion in the archaeological materials of mobile households, we conclude that sampling and mixing processes tend to introduce sufficient noise to overwhelm the occupancy signal.

This analysis demonstrates one of the ways that archaeologists can use ethnoarchaeological studies to explore the relative effects of error-generating processes that impinge on the formation of archaeological records. By generating explicit models of systemic behavior and site formation, it may be possible to unpack the complexities of archaeological records to arrive at substantive inferences about past behaviors. This study focused on the effect of occupancy on dispersion in the use of house space. However, there are many processes that conceivably structure the use of household space among the Dukha and other mobile societies. From Figure 3, and given the finding of central tendency, it should be apparent that there is clear structure in how space is used, and we have observed a number of candidate behaviors that may be influencing multiple dimensions of that variation. The Dukha Ethnoarchaeological Project continues to explore such relationships, and it is hoped that others will similarly explore the drivers of structured use of space among mobile societies in the interest of further advancing theories of archaeological site formation.

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## Disclosure statement

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*Matt O'Brien* is an Assistant Professor at California State University, Chico studying hunter-gatherer archaeology in the western United States. Past archaeological research includes Paleoindians of the Central and Southern Rockies and examining social organization through archaeofaunal remains. The ethnoarchaeology of spatial behavior among the Dukha represents his latest research effort.

## References

Agostinelli, C., and U. Lund. 2013. *R Package "Circular": Circular Statistics* (Version 0.4-7). https://r-forge.r-project.org/projects/circular/.

Alperson-Afil, Nira, Gonen Sharon, Mordechai Kislev, Yoel Melamed, Irit Zohar, Shosh Ashkenazi, Rivka Rabinovich, et al. 2009. "Spatial Organization of Hominin Activities at Gesher Benot Ya'aqov, Israel." *Science* 326 (5960): 1677–1680.

Arnold, Jeanne E. 2012. *Life at Home in the Twenty-First Century: 32 Families Open Their Doors*. Los Angeles: Cotsen Institute of Archaeology Press.

Audouze, Françoise, and James G. Enloe. 1997. "High Resolution Archaeology at Verberie: Limits and Interpretations." *World Archaeology* 29 (2): 195–207. doi:10.1080/00438243.1997.9980373.

Binford, Lewis R. 1981. "Behavioral Archaeology and the 'Pompeii Premise'." *Journal of Anthropological Research* 37 (3): 195–208.

Binford, Lewis R. 1983. *In Pursuit of the Past: Decoding the Archaeological Record*. Berkeley: University of California Press.

Bodu, P., C. Karlin, and S. Ploux. 1990. "Who's Who? The Magdelenian Flintknappers of Pincevent, France." In *The Big Puzzle: International Symposium on Refitting Stone Artefacts*, edited by Erwin Cziesla, S. Eikhoff, N. Arts, and D. Winter, 142–163. Bonn: Holos.

Carr, Christopher. 1991. "Left in the Dust: Contextual Information in Model-Focused Archaeology." In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll, and T. Douglas Price, 221–256. Interdisciplinary Contributions to Archaeology. New York: Plenum Press.

Clark, John E. 1986. "Another Look at Small Debitage and Microdebitage." *Lithic Technology* 15 (1): 21–33.
Clark, John E. 1991. "Flintknapping and Debitage Disposal among the Lacandon Maya of Chiapas, Mexico." In *The Ethnoarchaeology of Refuse Disposal*, edited by Edward Staski, and Livingston Delafield Sutro, 63–79. Anthropological Research Papers, 0271-0641; No. 42; Anthropological Research Paper; No. 42. Phoenix: Arizona State University.
Clark, Amy E. 2017. "From Activity Areas to Occupational Histories: New Methods to Document the Formation of Spatial Structure in Hunter-Gatherer Sites." *Journal of Archaeological Method and Theory* 1–26. doi:10.1007/s10816-017-9313-7.
Inamura, Tetsuya. 2005. "The Transformation of the Community of Tsaatan Reindeer Herders in Mongolia and Their Relationships with the Outside World." *Senri Ethnological Studies* 69: 123–152.
Johansen, Lykke, and Dick Stapert. 2003. *Oldeholtwolde: A Hamburgian Family Encampment Around a Hearth*. Boca Raton: CRC Press. doi:10.1201/b16993.
Koetje, Todd A. 1983. *Fouilles de Pincevent: Essai D'analyse Ethnographique D'un Habitat Magdalenien: la Section 36*. Paris: Editions du Centre national de la recherche scientifique.
Koetje, Todd A. 1987. *Spatial Patterns in Magdalenian Open Air Sites From the Isle Valley, Southwestern France*. British Archaeological Reports Limited.
Koetje, Todd A. 1994. "Intrasite Spatial Structure in the European Upper Paleolithic: Evidence and Patterning From the SW of France." *Journal of Anthropological Archaeology* 13 (2): 161–169. doi:10.1006/jaar.1994.1011.
Kroll, Ellen M., and T. Douglas Price, eds. 1991. *The Interpretation of Archaeological Spatial Patterning*. Interdisciplinary Contributions to Archaeology. New York: Plenum Press.
Leroi-Gourhan, André, and Michel Brézillon. 1966. "L'habitation magdalénienne n° 1 de Pincevent près Monterau (Seine-et-Marne)." *Gallia Préhistoire* 9 (2): 263–385. doi:10.3406/galip.1966.1264.
Leroi-Gourhan, André, and Michel Brézillon. 1983. *Fouilles de Pincevent: Essai d'analyse ethnographique d'un habitat magdalenien : la section 36*. Paris: Editions du Centre national de la recherche scientifique.
O'Connell, J. F. 1987. "Alyawara Site Structure and Its Archaeological Implications." *American Antiquity* 52 (1): 74–108. doi:10.2307/281061.
O'Connell, James F. 1995. "Ethnoarchaeology Needs a General Theory of Behavior." *Journal of Archaeological Research* 3 (3): 205–255.
O'Connell, James F., K. Hawkes, and N. G. Blurton-Jones. 1992. "Patterns in the Distribution, Site Structure and Assemblage Composition of Hadza Kill-Butchering Sites." *Journal of Archaeological Science* 19 (3): 319–345. doi:10.1016/0305-4403(92)90020-4.
R Core Team. 2013. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing. http://www.R-project.org/.
Schiffer, Michael B. 1972. "Archaeological Context and Systemic Context." *American Antiquity* 37 (2): 156–165. doi:10.2307/278203.
Schiffer, Michael B. 1985. "Is There a 'Pompeii Premise' in Archaeology?" *Journal of Anthropological Research* 41 (1): 18–41.
Schiffer, Michael B., Kacy L. Hollenback, James M. Skibo, and William H. Walker. 2010. *Behavioral Archaeology: Principles and Practice*. London: Equinox Pub.
Simek, Jan F. 1984a. *K-Means Approach to the Analysis of Spatial Structure in Upper Paleolithic Habitation Sites : Le Flageolet I and Pincevent Section 36*. Oxford: BAR Publishing.
Simek, Jan F. 1984b. "Integrating Pattern and Context in Spatial Archaeology." *Journal of Archaeological Science* 11 (5): 405–420. doi:10.1016/0305-4403(84)90021-9.
Stapert, Durk. 1989. "The Ring and Sector Method: Intrasite Spatial Analysis of Stone Age Sites, with Special Reference to Pincevent." *Palaeohistoria* 31 (0): 1–57.
Stapert, Dick, and Martin Street. 1997. "High Resolution or Optimum Resolution? Spatial Analysis of the Federmesser Site at Andernach, Germany." *World Archaeology* 29 (2): 172–194. doi:10.1080/00438243.1997.9980372.
Stevenson, Marc G. 1985. "The Formation of Artifact Assemblages at Workshop/Habitation Sites: Models From Peace Point in Northern Alberta." *American Antiquity* 50 (1): 63–81. doi:10.2307/280634.

Stiger, Mark. 2006. “A Folsom Structure in the Colorado Mountains.” *American Antiquity* 71 (2): 321–351. doi:10.2307/40035907.

Surovell, Todd A., and Matthew O’Brien. 2016. “Mobility at the Scale of Meters.” *Evolutionary Anthropology: Issues, News, and Reviews* 25 (3): 142–152. doi:10.1002/evan.21487.

Surovell, Todd A., and Nicole M. Waguespack. 2007. “Folsom Hearth-Centered Use of Space at Barger Gulch, Locality B.” In *Frontiers in Colorado Paleoindian Archaeology: From the Dent Site to the Rocky Mountains*, edited by Robert H. Brunswig, and Bonnie L. Pitblado, 219–259. Boulder: University Press of Colorado.

Surovell, Todd A., Nicole M. Waguespack, James H. Mayer, Marcel Kornfeld, and George C. Frison. 2005. “Shallow Site Archaeology: Artifact Dispersal, Stratigraphy, and Radiocarbon Dating at the Barger Gulch Locality B Folsom Site, Middle Park, Colorado.” *Geoarchaeology* 20 (6): 627–649. doi:10.1002/gea.20071.

Walker, Marilyn. 2009. “The Reindeer Herders of Northern Mongolia: Community, Ecology, and Spirit Matters.” *Communities; Rutledge* 143 (Summer): 35–39.

Wheeler, W. A. 2000. “Lords of the Mongolian Taiga: An Ethnohistory of the Dukha Reindeer Herders.” *Unpublished master’s thesis*, Indiana University.

Yellen, John. 1977. *Archaeological Approaches to the Present: Models for Reconstructing the Past*. New York: Academic Press.