Martu ethnoarchaeology: Foraging ecology and the marginal value of site structure

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ABSTRACT

Archaeological investigations of hunter-gatherer site structure have remained largely descriptive, despite significant explanatory advancements by evolutionary approaches to foraging behavior and ecology. To date, calls to incorporate site structure studies within this behavioral ecological framework have largely been ignored. We suggest there is a clear explanation for this. At large spatial extents, human behavior is constrained by patterned ecological variability, as such, a general theory of behavior is likely to characterize key aspects of human decisions. At small spatial extents, human behavior is not constrained by patterned ecological variability, therefore, the human decisions that produce site structure should be driven by mechanical constraints or random variation. However, variation in site structure may be ecologically relevant inasmuch as it informs on landscape level variation in human-environment interactions. Drawing on ethnoarchaeological data collected in collaboration with Martu, Aboriginal foragers in Western Australia, here we test empirically-derived, mechanistic predictions on site size and material size sorting to show how these can inform theoretically-derived, adaptive predictions from the Marginal Value Theorem. Results show that site size increases with the number of occupants and hence, the amount of in-patch foraging competition, while size sorting increases with the duration of occupation and hence, in-patch residence time. Combined, these attributes of site structure can be used as proxies of foraging behavior to explain variability in overall foraging yields. With this approach, site structure can provide insights into foraging decisions that can be examined through a general theory of behavior.

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1. Introduction

Ecological and evolutionary approaches in hunter-gatherer archaeology continue to make tremendous strides toward explaining variation in subsistence (e.g., Broughton et al., 2011; Speth, 2010), settlement (e.g., Byrd et al., 2015; Winterhalder et al., 2010), technology (e.g., Surovell, 2012; Stevens and McElreath, 2015), storage (e.g., Morgan, 2012; Whelan et al., 2013), and demography (e.g., Kelly et al., 2013; Williams et al., 2015). But despite this progress, studies of site structure remain largely descriptive (e.g., Hill et al., 2011; Speth et al., 2012).

O'Connell (1995) made this same observation twenty years ago, noting the disparity between ethnoarchaeological studies of faunal remains and those of site structure. While the former were advancing successful explanatory frameworks, the latter remained stagnant. O'Connell suggested a simple, yet under-appreciated reason

for this difference: studies of faunal remains were building on the foundations of a general theory which provided predictions *a priori* about how individuals are expected to behave in particular circumstances, but studies of site structure were based only on observations *a posteriori* without any guiding theory. Because the former predictions come from a general theory, they produce *deductive* inferences that should be true in all cases and therefore do not need to rely on direct ethnographic analogy in order to link ethnographic findings to the archaeological record. Because the latter predictions come from empirical observations, they produce *inductive* inferences that must be tested in every case and cannot escape the problems of direct ethnographic analogy. It stands to reason then, for studies of site structure to move forward, they must begin with a general theory. Yet despite this seemingly simple fix, archaeologists guided by a general theory, such as behavioral ecology, have failed to meet O'Connell's challenge.

We argue that there is a clear and simple reason for this: because movement at small spatial extents should not be significantly constrained by ecology, patterning in site structure will

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either be explained by simple mechanical parameters (e.g., human body size; Binford, 1983) or random variation. However, movement at larger spatial extents should be significantly constrained by dynamic ecological patterning, and as such, can be explained by a general theory such as evolution by natural selection (e.g., Bird and O'Connell, 2006; Codding and Bird, 2015; O'Connell, 1995). If this is true, then site structure can only be informed by a general theory of behavior inasmuch as site-level patterning is driven by larger, landscape scale decisions (including subsistence strategies, settlement and mobility; e.g., Binford, 1980; Kent, 1991).

In an attempt to incorporate studies of site structure within a general theory of behavior, here we link two common empirically-derived, mechanistic predictions about site structure to two theoretically-derived, adaptive predictions from a simple behavioral ecological model known as the Marginal Value Theorem (MVT, Charnov, 1976; Charnov and Parker, 1995). Then we test these predictions with ethnoarchaeological data collected in collaboration with Martu, an Aboriginal population who reside in and have native title over their ancestral estates in Western Australia.

2. Predictions

Behavioral ecological archaeologists focus on developing *adaptive* explanations of past human decisions that can be tested with material remains (Bird and O'Connell, 2006; Codding and Bird, 2015). As outlined by Tinbergen (1963), adaptive explanations examine the evolutionary function of behaviors in how they contribute to survival and reproductive success. But this is only one of four levels of explanations commonly employed to explain behavior. The others include *mechanistic* explanations, which focus on proximate causal factors, *ontogenetic* explanations, which focus on understanding how behaviors develop through the life course, and *phylogenetic* explanations which focus on how a particular behavioral trait evolved within a linage (Tinbergen, 1963). As discussed above, predictions about site structure typically fall within the mechanistic level. Here we attempt to link two of these mechanistic proposals to adaptive predictions derived from the MVT.

2.1. Mechanistic predictions

Several mechanistic "rules" of site structure have been proposed and tested with ethnographic or ethnoarchaeological data over the last seventy-five years (reviews in David and Kramer, 2001). Two of these are of particular relevance to the Marginal Value Theorem. These involve site size and the degree of size sorting.

First, because multiple people cannot occupy the same space while completing domestic tasks, the size of a site should increase with the number of occupants, of course, with all else being equal (e.g., tasks undertaken, kin-based residential rules, need for defense, etc.). This pattern was first described and tested by Cook and Treganza (1950) and subsequently confirmed by prominent ethnoarchaeologists working across the world (e.g., Yellen, 1977).

Second, because small discarded materials are likely to be dropped *in situ* (e.g., Binford, 1978a) and because large discarded materials will hinder ongoing activities within a site, people are likely to move larger items away from central activity areas (Hayden and Cannon, 1983) while overlooking smaller items. This causes significant size sorting wherein larger materials will tend to be more dispersed and smaller materials will tend to remain near the point of primary deposition (O'Connell, 1987). Importantly, the degree of size sorting should be contingent on the duration of occupation: as individuals stay longer at a site, it becomes worth-

while to remove obtrusive waste (O'Connell, 1987, 100); at least up to some threshold where it becomes less costly to move to a new camp and start over (O'Connell, 1977). The amount of small material remaining *in situ* should decrease proportionally with the efficiency of the cleaning technology (O'Connell, 1987, 92).

These predictions suggest that with hunter-gatherer camps, the size of a site should be a reliable indicator of the number of people (and number of active foragers if proportional to the number of people) who occupied it and the degree of size sorting should provide information on the duration of site occupation. Site size may also increase with the actual (Yellen, 1977) or anticipated (e.g., Kent, 1992; Kent and Vierich, 1989) duration of occupation, which may present a potential confound, but this is something that can be examined empirically.

2.2. Adaptive predictions

Based on the premise that natural selection should favor optimal food acquisition strategies, the MVT provides a framework to understand how long a forager should search for resources within a discrete patch before leaving to travel to a neighboring patch (Charnov, 1976; Charnov and Parker, 1995). Because a forager depresses the abundance of resources by removing them (Charnov et al., 1976), the energy acquired within a patch diminishes as a function of time spent in the patch (Fig. 1). Following Charnov and Parker (1995), the cumulative energy gain (G_t) within a patch can be described as:

$$G_t = G_m[1 - exp(-c \cdot t)] \tag{1}$$

where t is the in-patch (foraging) time, G_m is amount of energy originally in the patch (i.e., pre-foraging) and c is the rate at which acquired energy reaches G_m. Because the cumulative gain diminishes over time, there should be an optimal threshold at which a forager should leave the patch and travel to another patch. Charnov and Parker (1995) approximate the optimal leave time (t^*) as:

$$t^* = \frac{\left(\frac{c \cdot \mu + 2}{c \cdot \mu + 1}\right) log(c \cdot \mu + 1)}{c} \tag{2}$$

where μ is the travel distance to the next nearest patch. The depletion rate (c) should be inversely proportional to the available energy in the patch (G_m) as a result of the increased time required to search the patch (if prey density remains constant; Charnov and Parker, 1995). In other words, larger patches have more resources, but take longer to search.

This model provides a clear framework to predict how the number of foragers within a patch and patch residence time should interact to the determine the amount of energy acquired per capita. Holding the available energy within a patch constant, when there are more people within a patch, per capita gains will be lower (divided between more people) and less time will be spent searching within the patch. Holding the number of foragers constant, when a patch has more energy, individuals will spend more time searching the patch, which will increase the optimal patch residence time. Fig. 1 illustrates these predictions with hypothetical scenarios.

While this model is specific to environmental situations where resources are patchily distributed, it holds for humans even if patches are homogeneous because humans are central place foragers (Orians and Pearson, 1979) who return acquired food to a home base. As such, human foraging segments environments into catchments around central places.