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Interpreting abundance indices: some zooarchaeological implications of Martu foraging

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ABSTRACT

Indices of taxonomic abundance are commonly used by zooarchaeologists to examine resource intensification, overexploitation and gender-divisions in foraging labor. The original formulation of abundance indices developed a clear interpretive framework by linking the measure with foraging models from behavioral ecology. However, using the same basic tenets of behavioral ecology, archaeologists disagree about how to interpret variability in abundance index values: some suggest that high proportions of large prey remains represent higher overall foraging efficiency, while others argue the opposite. To help solve this problem, we use quantitative observational data with Martu hunters in Australia's Western Desert to examine how foraging decisions and outcomes best predict variation in the abundance index values that result. We show that variation in the proportional remains of large to small game is best predicted by hunting bout success with larger prey and the time spent foraging for smaller prey. A declining abundance index results from decreasing hunting success with larger prey, increasing time invested in hunting smaller prey, or both; any of which result in a lower overall return rate than if large prey were acquired reliably. We also demonstrate that where large prey acquisition is stochastic, high index values are correlated positively with men's proportional caloric contribution of large unreliable game, while low index values are correlated with women's proportional foraging time for small reliable game. We discuss these results with reference to evidence of resource intensification and gender-specific foraging.

1. Introduction

In the last few decades, zooarchaeological studies have made important contributions to our understanding of prehistoric human behavior and human-prey dynamics, providing new insights into broad-spectrum revolutions (e.g., Stiner, 2001; Stutz et al., 2009), anthropogenic resource depression (e.g., Broughton, 1994; Cannon, 2003), human caused extinction events (Jones et al., 2008a; Nagaoka, 2002), and variability in gender-divisions of foraging labor (e.g., Kuhn and Stiner, 2006; McGuire and Hildebrandt, 2005). Many of these studies rely on indices of taxonomic abundance to evaluate diachronic variability in prehistoric foraging efficiency and resource choice (see review in Bird and O'Connell, 2006; Lupo, 2007).

Abundance indices (AI) measure the relative profitability of a foraging strategy by calculating the proportion of higher ranking taxa relative to lower ranking taxa in a zooarchaeological assemblage. The initial approach was developed by Bayham (1979) as a means to evaluate predictions of the encounter-contingent prey choice model (PCM) from behavioral ecology (see Charnov and Orians, 1973; MacArthur and Pianka, 1966; Schoener, 1971; Stevens and Krebs, 1986; see also Bettinger, 1991, 2009). The basic PCM assumes that a forager's main goal is to maximize the rate at which energy is acquired. To achieve this goal, a forager searching for homogenously distributed resources within a patch should always pursue the resource with the highest post-encounter profitability when encountered and should only pursue less profitable resources when the opportunity costs of handling them are less than what could be gained by continuing to search for more profitable prey. Thus, when the encounter rates with the highest ranking prey are frequent enough, foragers should only take that resource. However, when the encounter rates with the highest ranking prey decline, the model predicts that foragers should respond by widening their "diet breadth" to include lower ranked resources, reducing a forager's overall efficiency. When resources are not distributed homogenously, this same logic can and has (e.g., Hildebrandt and Jones, 1992; see also Broughton, 1994) been applied to resource patches (see Bettinger, 1991; MacArthur and Pianka, 1966) or foraging activities (Smith, 1991); both of which

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can be thought of as the PCM operating at a larger scale. In such cases, patches or activities are ranked by their energetic return rate and as with the standard PCM, whether or not a forager should enter a patch type or be involved in a foraging activity depends on the abundance of the highest ranking patch in the environment or the abundance of resources within the highest ranking patch. Because neither post-encounter profitability within a patch, nor the profitability of a resource patch or activity type overall can be observed archaeologically, Bayham (1979, 1982) argued that resource rank should scale with prey body size (see Griffiths, 1975) and that the addition of smaller prey is a function of declining encounters with larger prey. Most applications of abundance indices have followed this lead, and as such, the model predictions shift to be specifically about large prey versus small prey (although, see e.g., Stiner et al., 2000; Jones et al., 2008b).

Based on this traditional framework, high proportions of large prey relative to small prey have been used as evidence for high overall forging return rates and a divergent gender division of labor focused on men's acquisition of larger prey (e.g., Broughton and Bayham, 2003; Broughton et al., 2008; see also Isaac, 1978). Diachronic declines in the abundance of large prey then suggest declines in overall foraging efficiency (e.g., Nagaoka, 2002), widening diet breadth associated with broad-spectrum revolutions (e.g., Stutz et al., 2009) and a gender division of labor in which reductions in large game necessitate the acquisition of smaller game by either men, women or both.

However, ethnographic and actualistic work has questioned the assumption that prey body size and prey rank are always positively correlated. Mass capture techniques may increase post-encounter return rates for some types of small prey, particularly fish and insects (Madsen and Kirkman, 1988; Madsen and Schmitt, 1998; Ugan, 2005a,b; Lupo and Schmitt, 2002, 2005). Moreover, under some circumstances, larger prey may be of lower rank than predicted due to the effects of relative prey mobility, which can increase with prey size, and may lead to higher instances of pursuit failure (Bird et al., 2009; see also Hawkes et al., 1991; Jochim, 1976; O'Connell et al., 1988; Smith, 1991:230–231; Stiner et al., 2000; Winterhalder, 1981:95–96). If this is the case, foragers may attain higher overall return rates by pursuing smaller prey that can be acquired more reliably. Because foragers (often men) continue to pursue larger prey despite the acquisition risk, it may be that the actual goals of foraging vary as a function of gender (Jochim, 1988), with men focused on maximizing currencies other than the rate of resource acquisition, such as social capital or prestige (Bliege Bird and Smith, 2005; Hildebrandt and McGuire, 2002). Instances of such behavior represent a clear violation of one of the primary assumptions of the PCM (e.g., Bliege Bird et al., 2001; Hawkes et al., 1991; Hill et al., 1987; see also Lee, 1968).

With this critique, an alternative interpretation of abundance indices has emerged in opposition to the traditional interpretation. This alternative view suggests that high proportions of large prey relative to small prey represent lower overall foraging efficiency (e.g., Hildebrandt and McGuire, 2002; McGuire et al., 2007) and a gender division in foraging labor in which men's pursuit of large prey is subsidized by women's labor focused on more reliable resources (Hildebrandt and McGuire, 2002; McGuire and Hildebrandt, 2005). Accordingly, diachronic declines in the abundance of larger prey relative to smaller prey then reflect increases in foraging efficiency and an increase in the overlap between men's and women's resource choice, both being focused on small prey (McGuire and Hildebrandt, 1994, 2005; but see also Jarvenpa and Brumbach, 2009; Kuhn and Stiner, 2006; Waguespack, 2005; Zeanah, 2004).

That opposite interpretations exist for a single quantitative measure is a problem for zooarchaeological analyses; if both interpretations are taken seriously, competing hypotheses about prehistoric foraging are rendered essentially untestable. However, despite being a static material outcome of complex and dynamic foraging decisions, abundance indices should still provide a relatively straightforward measure of variability in the outcomes of human foraging. That is, where we can control for the effects of differential transport and post-depositional processes, abundance indices should reflect some aspect of the trade-off between hunting larger and smaller prey. As such, actualistic research can provide direct evaluation of the parameters of such trade-offs and the zooarchaeological patterns they produce.

Here we undertake an empirical exercise to examine the meaning of abundance indices. We ask (1) *how does foraging behavior predict variation in abundance indices*? And (2) *how do differences in men's and women's foraging decisions explain variation in abundance indices*? To answer these questions, we draw on quantitative foraging data collected with Martu, a group of Aboriginal Australians living in arid Western Australia. Specifically, we examine the trade-off between hunting hill kangaroo (*Macropus robustus*) and sand monitor lizards (*Varanus gouldii*), two major resources that embody the trade-offs between hunting larger and smaller prey. First, we test predictions derived from the traditional interpretation of abundance indices to examine how the overall rates of energetic return, total foraging time, hunting success and total harvest size for hill kangaroo and sand monitors predict abundance index values. Second, we test predictions derived from the traditional interpretation of abundance indices to examine how gender-differences in foraging strategies are reflected by variability in abundance index values. Following O'Connell (1995), this approach allows predictions derived from general theory of behavior to be tested simultaneously with observations and their archaeological correlates, thus avoiding the problems associated with simple analogy. As such, even though Martu hunting does not represent all variability in prehistoric or even contemporary hunting, the basic links between human foraging decisions, prey size, mobility, foraging returns and their relative impacts on abundance indices should provide a baseline that can help guide future analyses and resolve some of the confusion surrounding their interpretation.

2. Contemporary Martu foraging

Martu, sometimes written as Mardu or Mardujarra, is used as a common term of self-reference for a set of Aboriginal Australian dialect groups whose homelands are centered around the Karlymillyi (Rudall) River and Percival Lakes in Western Australia's Gibson, Little Sandy and Great Sandy Deserts (Fig. 1). Some of these groups came into contact with European Australians in the mid-late 1960s and were subsequently settled onto missions and cattle stations (Davenport et al., 2005; Scelza and Bliege Bird, 2008; Tonkinson, 1991, 1974). After a 20-year hiatus, many Martu returned to their homelands and today have Native Title over their traditional estates. Life in the desert is primarily centered in one of three remote communities or outstations: Parnngurr, Punmu and Kunawarritji. This work is focused in Parnngurr community, which is home to Martu mainly from the Manyjiljarra, Warnman and Kartujarra dialect groups.

Subsistence hunting remains of central importance to Martu in these communities. Hunting parties are sometimes planned in advance, but more frequently emerge ad hoc on a given day. Through open discussion, sometimes occurring partially en route, individuals decide on the motor vehicle they will take, which region they will travel to and the hunting activities they will engage in. On arrival, the party establishes a "dinner-time" camp. Foragers depart on foot from this camp and will later return to process, cook