Journal of Archaeological Science 38 (2011) 1798–1809

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Split phalanges from archaeological sites: evidence of nutritional stress?

Jennie J.H. Jin [a,*], Edward W. Mills [b]

[a] Department of Anthropology, The Pennsylvania State University, University Park, PA 16802, USA
[b] Department of Dairy and Animal Science, The Pennsylvania State University, University Park, PA 16802, USA

ARTICLE INFO

Article history:
Received 21 October 2010
Received in revised form
1 March 2011
Accepted 10 March 2011

Keywords:
Phalanges
Resource intensification
Nutritional stress
Yunnan
China
Experimental studies
Optimal foraging theory

ABSTRACT

Broken animal phalanges from archaeological sites have been widely used as an indicator of nutritional stress of the prehistoric people due to the low caloric return rate (caloric yield/processing time) of the phalanges. Although it sounds logical, this widely popular argument is based on Binford's (1978) interview with the Nunamiut and lacks empirical support. In this study, we present the results of experimental studies conducted on 142 modern cow (*Bos taurus*) and deer (*Odocoileus virginianus*) first phalanges to document the processing of phalanges, such as the required force and processing time to break them open, possible methods of breaking phalanges, and the resultant breakage and surface modification patterns. This comparative dataset and ethnographic data from contemporary hunter-gatherer groups indicate that broken phalanges in and of themselves cannot be taken as evidence of resource stress. The phalanges do not require substantial amount of processing time and marrow from the phalanges could have been preferred for its taste and soft texture during the period when resources were not scarce. This may explain the bone breakage pattern from an 8800 year old archaeological assemblage from Tangzigou in southwest China, where phalanges were intensively broken without any other evidence of resource stress.

1. Introduction

The interpretation of zooarchaeological assemblages requires caution because the exact activities involved in prehistoric hunting and butchering are unknown. Ethnographic studies of the contemporary hunter-gatherers and actualistic studies with controlled experiments have provided valuable insights in filling this gap (e.g., Yellen, 1977a,b; Binford, 1978, 1981; Brain, 1981; Shipman, 1983, 1986; Shipman and Rose, 1983a,b; Bunn et al., 1988; O'Connell et al., 1988, 1990, 1991; Blumenschine, 1988, 1995; Marean et al., 1992; Bartram, 1993; Lupo, 1994; Monahan, 1998; Abe, 2005; Garvey, 2010). These studies have documented the relationship between human foraging behavior and the pattern of faunal assemblages produced as a result. The mode of carcass acquisition (i.e., hunting vs. scavenging), carcass treatment and transportation decisions are the topics that have generated vigorous and fruitful discussions and debates in the past thirty years.

Tremendous variation in foraging behavior can be seen by comparing the choices made by different people with regard to carcass transportation. The Nunamiut field processed caribou carcasses and selectively transported the body parts with higher edible meat yields (Binford, 1978), while the Evenki of Siberia transported the whole reindeer carcass regardless of individual parts' nutritional utility (Abe, 2005). The Hadza fillet meat prior to transport, leaving the bones at the kill/processing site (O'Connell et al., 1988), while the !Kung and Okiek usually fillet at their residential sites (Yellen, 1977a,b; Marshall, 1991, 1994). This variation makes it difficult to interpret the skeletal element representation and bone surface modification data from archaeological sites.

The optimal foraging model of behavioral ecology has become a powerful analytical tool to explain this variation by examining the underlying factors in foraging decision making. The assumption of the optimal foraging model is that "the goal of foraging is to maximize the overall energy return-rate" (Kelly, 1995: 83). A consistent relationship has been found between the mean foraging return rate and the degree of carcass processing in contemporary foraging groups in spite of the variation in hunting and butchering behavior (Burger et al., 2005). That is, people will make the most cost-efficient choice based on the amount of nutrients and processing time associated with different animal body parts (Jones and Metcalfe, 1988; Bettinger, 1991; Kelly, 1995; Lupo, 1998; Madrigal and Holt, 2002; Bird and O'Connell, 2006).

* Corresponding author. Present address: Joint POW/MIA Accounting Command Central Identification Laboratory (JPAC-CIL), Joint Base Pearl Harbor-Hickam, HI 96853, USA. Tel.: +1 808 352 1721; fax: +1 808 448 1982.
E-mail addresses: jennie.jin@hotmail.com (J.J.H. Jin), ewm3@psu.edu (E.W. Mills).

0305-4403/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jas.2011.03.013

The forager is expected to stop processing the carcass at the point when the rate of gain decelerates significantly despite of the prolonged handling time (Charnov, 1976; Kelly, 1995; Burger et al., 2005). The optimal foraging model predicts that a forager will process body parts with a low return rate, such as the mandible, scapula, and phalanges, when resources with a higher return are scarce. Thus, intensive processing of the low return rate bones has been commonly interpreted as an evidence of nutritional stress.

Cervid and bovid phalanges from Tangzigou, an 8800 year old archaeological site from southwestern China, were broken extensively, suggesting that the Tangzigou people might have been under resource stress during the time of site formation (Jin, 2010; see below). However, the analysis of other skeletal elements with higher return rates from Tangzigou did not show evidence of intense processing, as would be expected if resource stress were high.

In this paper, we articulate and test the optimal foraging hypothesis using the dataset from Tangzigou, arguing that the intensively processed phalanges in and of themselves cannot be evidence of resource stress. First, we present the results of experimental studies conducted on 142 modern domestic cattle (*Bos taurus*) and white-tailed deer (*Odocoileus virginianus*) first phalanges (PH1) to document the processing of phalanges, such as the required force and processing time to break them open, possible methods of breaking phalanges, and the resultant breakage and surface modification patterns. This experimental dataset and ethnographic data are then compared with the broken phalanges from zooarchaeological assemblages such as Tangzigou.

2. Background and hypothesis

Phalanges are usually perceived as bones not worth processing for two reasons. First, phalanges are difficult to access due to the tough surrounding ligaments and tendons. Second, phalanges are not surrounded by consumable meat and have little marrow in the first (PH1) and second phalanges (PH2) and none in the third one (PH3). The femur, one of the highest-utility body parts, yields approximately fourteen times more calories from the marrow than the PH1 and PH2 in white-tailed deer (Madrigal and Holt, 2002; also see Jones and Metcalfe, 1988; Emerson, 1990).

The Nunamiut did not process phalanges during Binford's stay for these two reasons, although the older informants pointed out that they broke the phalanges for marrow when the food was scarce (Binford, 1978). This led Binford (1978) to argue that the intensity of phalanx processing can be used as "a measure of the subsistence security enjoyed by a group at the time of observation" (p. 32). Ever since Binford's (1978) observation, phalanges have been considered to be a food resource that generally was butchered during hard times when people were under nutritional stress (Jones and Metcalfe, 1988). Intensively broken phalanges from archaeological sites have therefore been interpreted as an evidence of resource scarcity (Munro and Bar-Oz, 2005; Bar-Oz and Munro, 2007; Hall, 2007; Hill, 2008).

The intensity of carcass processing in a zooarchaeological assemblage can be detected by analyzing the degree of bone fragmentation, which can be measured by the percentage of completeness (%completeness or complete bone MNE/total MNE) and the fragmentation ratio (NISP:MNE) (Todd and Rapson, 1988; Outram, 2001; Burger et al., 2005; Munro and Bar-Oz, 2005; Pickering and Egeland, 2006; Bar-Oz and Munro, 2007). Intensively processed carcasses will have a low % completeness ratio and a high fragmentation ratio. Therefore, when the gazelle assemblages from five Epipaleolithic sites in the Levant studied by Munro and Bar-Oz (2005) showed significant positive correlations between the fragmentation ratio of the skeletal elements and their marrow yields, the researchers argued that this was evidence of resource scarcity and extensive utilization of the animal carcasses (Munro and Bar-Oz, 2005). Prendergast et al. (2009) used the same method to show that the extensive breakage of the deer phalanges from a Late Pleistocene cave site in southern China was evidence of resource intensification.

3. Faunal assemblage from Tangzigou

Tangzigou (N 25°1′31″, E 99°0′28″; 1360 m above sea level) is an open-air archaeological site located in Yunnan Province of southwest China (Fig. 1). It is a flat area of ~300 m^2 located on top of a small hill along the Pupiao River in the Pupiao Basin in Baoshan Prefecture. At the time the site of Tangzigou formed, there appears to have been a small lake to the northwest and an extensive wetland along the Pupiao River in front of the site (G. Chaplin, pers. comm.). The habitat preferences of the micromammal species recovered from Tangzigou indicate that the area was covered with subtropical forest, including pockets of moist bamboo forest, at the time the assemblage accumulated (Jin et al., in preparation). The broad range of rock sizes and sediment particle shapes found at Tangzigou are indicative of a colluvial deposit. The current geological setting of the Pupiao Basin and the state of bone preservation also suggest that the faunal assemblage has moved only a short distance downslope from the original deposition site, probably by runoff during multiple rainstorms (Jin, 2010). This suggests that the vegetation was sparse or at least not dense at the site, allowing the sediments to be washed away.

Once the top compact soil was removed (~25 cm deep), bones and artifacts were found in great concentrations. The lack of stratigraphic distinction within the layer bearing artifacts and bones suggested that the bones and artifacts could be treated as one assemblage that accumulated over a short time period. This inference was supported by the result of Accelerator Mass Spectrometry radiocarbon dating of the carbon samples with good provenance (Peking University Radiocarbon Laboratory. Sample numbers: BA04271-04275). The data confirmed that the site was deposited over a short period of time. The most superficial layer where bones and artifacts were found was dated to 8800 ± 40 cal yrs BP and the deepest layer ~1 m deep from the surface was dated to 9000 ± 40 cal yrs BP (Fig. 2).

Since its first excavation in 1987, Tangzigou has been excavated several times, most recently in 2003 and 2006. All of the excavated sediments were dry- and wet-sieved through 3 mm mesh screens. Numerous stone and bone tools, vertebrate and invertebrate fossils, and plant macrofossils have been discovered. Tangzigou stone tools appeared to be very similar to the Hoabinhian assemblage from Southeast Asia and mainly consisted of flaked pebble tools lacking sharp working edges. No pottery was found. The mammal fauna consists of 5358 identifiable specimens and 3360 unidentifiable fragments. Cervids and bovids are the most abundant taxa. Small cervids, the size of a muntjac (<50 kg), dominate the assemblage (53% of the total NISP). Sambar-sized large cervids (>150 kg) (22%) and water-buffalo-sized large bovids (>600 kg) (19%) are the next most abundant groups. Small mammal accounts for the rest of the materials.

Zooarchaeological and taphonomic analysis of the Tangzigou assemblage strongly suggests that Tangzigou was a butchery site rather than a residential site for the hunter-gatherers (Jin, 2010). Tangzigou people carried the animal carcasses up to the site probably because it was an elevated area with sparse or at least not dense vegetation in a wooded environment. Thus, the site could have served as a vantage point from which people could watch out for predators and process the carcasses. Large boulders and